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ABSTRACT

Sixteen self-study waterworks operators training modules are provided. Module titles are the following: basic mathematics, basic chemistry, analysis procedures, microbiology, basic electricity, hydraulics, chlorination, plant operation, surface water, ground water, pumps, cross connections, distribution systems, safety, public relations, and management. Each module generally includes a list of performance objectives, module pretest with answer key, information sections, self-tests for each section with answer keys, and a post evaluation with answer key. (Author)

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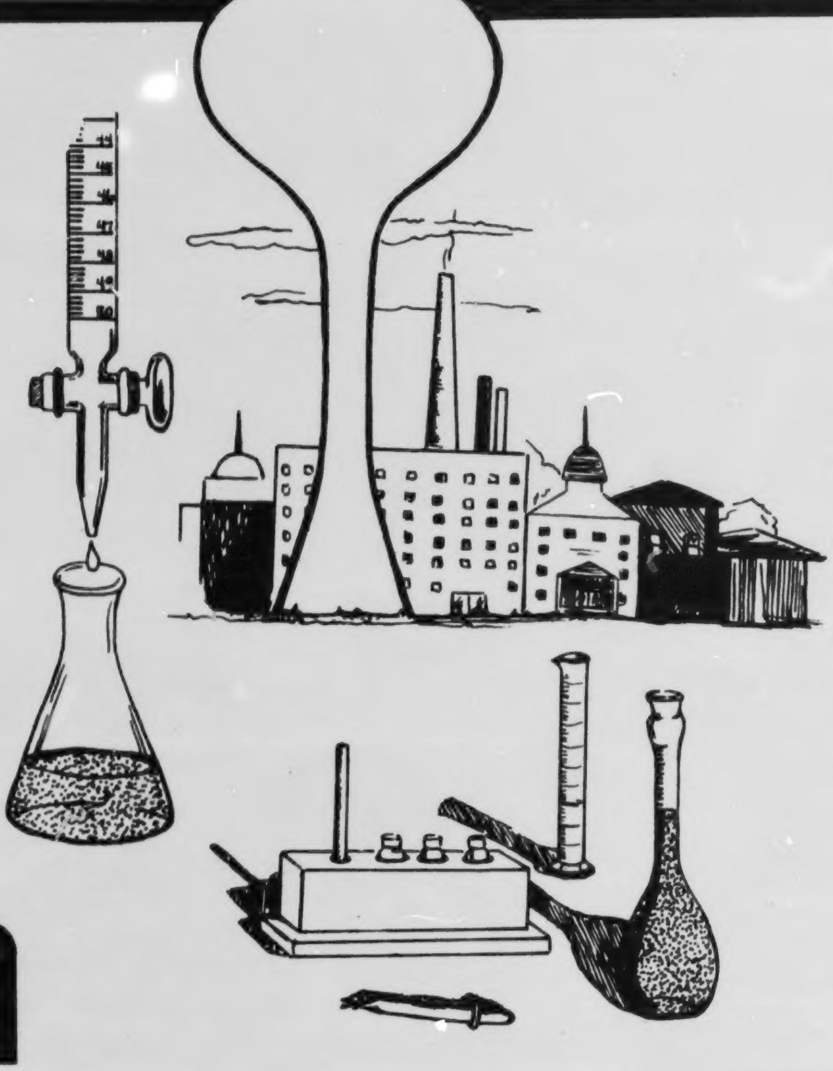
Waterworks Operator Training Manual

Developed by
Office of Career Programs and Division of Science
Northeast Missouri State University
Kirksville, Missouri



In Cooperation with
The
Missouri Department
of
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and
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CE 022 606

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PREFACE

The sixteen waterworks operators training modules were prepared to assist waterworks employees to gain fundamental skills and knowledge needed to be a competent and safe worker, and write the licensure examination for C & D level. The modules were designed for self study. However, it is recommended that they be supplemented with classroom instruction to provide for classroom interaction, question and answer and a multi-media approach to instruction enrichment. This project was funded through the Vocational Division of the Department of Elementary and Secondary Education with a portion of the funds coming from an Environmental Protection Agency grant. Northeast Missouri State University was the contract recipient and their staff utilized the consultative service of the Department of Natural Resources and a strong advisory committee to provide direction for content, format of the modules.

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WATERWORKS OPERATOR

MODULE 1 BASIC MATHEMATICS

MODULE 2 BASIC CHEMISTRY

MODULE 3 ANALYSIS PROCEDURE

MODULE 4 MICROBIOLOGY

MODULE 5 BASIC ELECTRICITY

MODULE 6 HYDRAULICS

MODULE 7 CHLORINATION

MODULE 8 PLANT OPERATIONS

MODULE 9 SURFACE WATER

MODULE 10 GROUND WATER

MODULE 11 PUMPS

MODULE 12 CROSS CONNECTIONS

MODULE 13 DISTRIBUTION SYSTEM
MODULE 14 SAFETY

MODULE 15 PUBLIC RELATIONS

MODULE 16 MANAGEMENT

MODULE 1

SELF-INSTRUCTIONAL

Paul Hummel - NMSU

BASIC MATHEMATICS

PREREQUISITES: None

Due to rounding errors and methods of calculation (e.g. by hand, by calculator), answers may vary slightly from those given in the text.

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION (4 pts. each answer)

1. add 21 to .0135 __________ add $\frac{2}{3}$ to $4\frac{5}{8}$ __________

2. from 2 take $\frac{5}{10}$ __________ from 5 take $1\frac{1}{4}$ __________

3. 8 + .0354 + 21.701 __________ $5\frac{1}{4} + 3\frac{1}{8} + 1\frac{1}{5}$ __________

4. 7 - .75 + .35 __________ $1\frac{2}{3} + 5\frac{1}{4} - 2\frac{1}{5}$ __________

5. multiply 7.1476 by .15 __________ divide 5.39 by .7 __________

6. what is $\frac{4}{5}$ of 35? __________ if $\frac{5}{9}$ of a number is 35, what is the number? __________

7. find .75 of 50 __________ what part of 72 is 30?

8. $\frac{9}{11} \times 3$ __________ 5 divided by $\frac{3}{5}$ __________

9. 90% changed to a decimal __________ 90% changed to a fraction __________

10. find 21% of 119.05 __________ 9 is 150% of what number? __________

11. convert 350 in. to ft. __________ 3.5 yards to feet __________

12. 2.5 pints to quarts __________ 270 ounces to pounds __________

13. .8 kg. to g. __________ 150 ml. to l. __________

14. 280 cm. to m. __________ 15 cm. to inches __________

15. 18 pounds to kg. __________ 8 pints to liters __________

16. Find the area of a table 3.5 feet long by 2.7 feet wide. __________

17. If the base of a water tank has a diameter of 40 inches, find its area in square feet. __________

18. Find the volume of a tool box 1.5 feet high, 2 feet 11 inches long, and .5 feet wide. __________

19. How much water will a ground storage reservoir hold if the tank is 75 feet in diameter and with a 15 foot depth? __________

20. A 750 million gallon reservoir is filled during a test in 7.5 hours. What is the pumping rate in gallons per hour? __________

21. A city of 3,000 population uses water at the rate of 125 gallons per person per 8 hour day. Figure out how much water must be pumped during an eight hour day to meet the demand in gallons per minute.

____

22. A ground level reservoir is 35 feet long, 30 feet wide and 10 feet deep. Calculate how many cubic feet of water it will hold. __________

23. A station pumps 600 gallons per minute to a city of 4,000 customers during an eight hour day. How many gallons does each person use per hour? __________

24.

Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
520,000	1,000,540	871,000	1,432,100	1,342,000	1,452,000	801,567

If this is a daily record of the number of gallons pumped from a plant, what is the average daily amount of water pumped for this week? __________

25. If a man laid 100 yards of pipe in three hours, how much could be laid in an eight hour day? __________

26. A basin with an inflow of 500 gallons per minute has chlorine added to it at a rate of 20 pounds per 24 hour day. How many ppm are being added? __________

27. How many pounds of a chemical is required to treat 2.5 M.G. to obtain a dosage of 1.5 gpg? __________

28. What is the filtration rate of a filter 10 feet by 5 feet which has 25 gpm flowing through it? __________

29. A water storage tank 25 feet tall with a circumference of 50 feet has water flowing through it at a rate of 25 gallons per minute. What is the detention time? __________

30. Define:

a. gpd

b. mgd

c. ppm

d. km.

e. mg./l.

f. m.

ANSWERS

1.	21.0135	$5\frac{7}{24}$
2.	$1\frac{1}{2}$	$3\frac{3}{4}$
3.	29.7364	$9\frac{23}{40}$
4.	6.6	$4\frac{43}{60}$
5.	1.07214	7.7
6.	28	63
7.	37.5	$\frac{5}{12}$ or 0.417
8.	$2\frac{5}{11}$ or 2.45	$8\frac{1}{3}$ or 8.33
9.	.9	$\frac{9}{10}$
10.	25	6
11.	29.17 ft.	10.5 ft.
12.	1.25 qt.	16.875 lbs.
13.	800 g.	.15 l.
14.	2.8 m.	5.91 in.
15.	8.18 kg.	3.78 l.
16.	9.45 sq. ft.	
17.	1256.637 sq. in. = 8.73 sq. ft.	
18.	2.19 cu. ft.	
19.	495,684.4 gals.	
20.	100 M.G./hr.	
21.	781.25 gal./min.	
22.	10,500 cu. ft.	
23.	9 gal. per hour	
24.	1,059,886.7 gal. per day	

25. 266.67 yards

26. 3.33 ppm

27. 535.5 lbs.

28. 0.5 gal. per sq. ft. per min.

29. 1488.1 min.

30. a. gpd = gallons per day

    b. mgd = million gallons per day

    c. ppm = parts per million

    d. km. = kilometers

    e. mg./l. = milligrams per liter

    f. m. = meter

INTRODUCTION

Much of your work in the water treatment plant will involve solving mathematical problems. This module will help you understand how to solve them.

PERFORMANCE OBJECTIVE

When this module is completed, you will be able to show that you have mastered the following concepts:

1. Addition, subtraction, multiplication, division
2. Fractions
3. Decimals
4. Percentages
5. Ratios and proportions
6. Perimeters, areas, volumes
7. Water treatment plant calculations
8. Problem solving

Mastery of this module will be shown by answering of the questions found in the Post-Evaluation with 70% accuracy.

INSTRUCTIONS

Read each of the following sections carefully. Study the examples and work the problems at the end of the module. Some of these problems may be assigned by your instructor or you may wish to do them on your own. The more problems you work the better you will understand the material presented in the section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module.

The self-tests are designed to review what you have learned in the previous section. To use the self-tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct.

BASIC OPERATIONS: ADDITION, SUBTRACTION, MULTIPLICATION, DIVISION

Addition

There are three general rules which we follow when adding whole numbers. These are as follows:

Rule 1. Keep all decimal points and numbers in columns.

For example:

$$\begin{array}{r} 15.42 \\ +\ 2.01 \\ \hline 17.43 \end{array}$$

Rule 2. Write down all carryover numbers.

For example:

$$\begin{array}{r} {}^{11}487 \\ +313 \\ \hline 800 \end{array}$$

Note: Carryover numbers should be written lightly over the next column to the left.

Rule 3. All numbers must be in the same dimensional units (inches, ounces, hours).

- Remember you can not add apples and oranges -

For example: 2 yds. plus 9 ft. must be added by converting feet to yards (Example 2) **or yards to feet** (Example 3).

(1) ~~2 yds.~~
~~+9 ft.~~

(2) 2 yds. = 2 yds.
9 ft. = + 3 yds.
5 yds.

(3) 2 yds. = 6 ft.
9 ft. = +9 ft.
15 ft.

Note: 5 yds. is the same as 15 ft.

Subtraction

The three rules for addition generally apply to subtraction since subtraction is the reverse of addition.

Rule 1. Keep all decimal points and numbers in columns

For example: subtract 0.521 from 7.753

$$\begin{array}{r} 7.753 \\ -\ 0.521 \\ \hline 7.232 \end{array}$$

Rule 2. Write down all borrowed numbers

Since subtraction is the reverse of addition, carryovers are not made, but "borrowing" is sometimes necessary.

For example: subtract 375 from 764

(1) the numbers are grouped in columns

$$\begin{array}{r} 764 \\ -\ 375 \\ \hline \end{array}$$

(2) borrow one from 6 (leaving five) and add ten to the four to get 14, subtract five from 14 and write down nine.

(3) borrow one from the seven and add ten to the five to get 15, subtract seven from 15 and write down eight.

(4) subtract three from six and write down three.

Column Labels

Hundreds	Tens	Units
7	6	4
- 1	- 1	+ 10
6	5	14
	+ 10	
	15	
- 3	7	5
3	8	9

OR

$$\begin{array}{r} {}^{6}7\ {}^{15}6\ {}^{1}4 \\ 3\ \ 7\ \ 5 \\ \hline 3\ \ 8\ \ 9 \end{array}$$

NOTE: To check your subtraction, add 389 to 375.

$$\begin{array}{r} 3\ 8\ 9 \\ \underline{3\ 7\ 5} \\ 7\ 6\ 4 \end{array} \qquad \text{(check)}$$

Rule 3. All numbers must be in the same dimensional units.

Multiplication

A short-cut method of addition is multiplication. For example, when we multiply 2 x 3, we are actually adding the 3's twice (x 2) or the 2's three times (x 3).

(1) 2 x 3 = 6

(2) 3 + 3 = 6

(3) 2 + 2 + 2 = 6

From these examples, we can see that one way of checking multiplication problems is by addition. It is much easier though to memorize the multiplication tables through 10.

To multiply larger numbers, the following procedure should be used.

Example: What is 41 times 32?

(1) 1 x 2 = 2 write down 2

$$\begin{array}{r} 32 \\ \underline{\times\ 41} \\ 2 \end{array}$$

(2) 1 x 3 = 3 write down 3

$$\begin{array}{r} 32 \\ \underline{\times\ 41} \\ 32 \end{array}$$

(3) 4 x 2 = 8 write down 8 in second row, but one place to the left.

$$\begin{array}{r} 32 \\ \underline{\times\ 41} \\ 32 \\ 8 \end{array}$$

(4) 4 x 3 = 12 write down 12

$$\begin{array}{r} 32 \\ \underline{\times\ 41} \\ 32 \\ \underline{128} \end{array}$$

(5) add the second set of numbers

$$\begin{array}{r} 32 \\ \underline{\times\ 41} \\ 32 \\ \underline{128} \\ 1312 \end{array}$$

There are two rules to remember in multiplication:

Rule 1. The number of decimal places in the answer is equal to the sum of decimal places in the numbers multiplied.

For example:

17.059	3 decimal places
2.75	+ 2 decimal places
85295	
119413	
34118	
46.91225	5 decimal places

Rule 2. Numbers do not have to have the same dimensional units. Unlike addition, multiplied numbers do not have to have similar dimensional units. Thus, one must specify the units that go with the numbers. These must be carried through to the answer.

For example:

A 7 foot lever with a 15 lb. weight on its end would produce:

7 ft. x 15 lb. = 105 ft. lbs.

The multiplication process can be indicated in one of five ways.

	Sign	Example
(1)	x	7 ft. x 15 lb. = 105 ft. lb.
(2)	( )	(7 ft.) (15 lb.) = 105 ft. lb.
(3)	[ ]	[7 ft] [15 lb.] = 105 ft. lb.
(4)	•	7 ft. • 15 lb. = 105 ft. lb.
(5)	combination of any of above	[7 ft] • 15 lbs. = 105 ft. lb.

If brackets or parentheses ( ) are used, make sure to complete the indicated operation within the brackets or parentheses first.

(1) For example: (30 - 5) (5 • 2) (8 + 2) =
(25) (10) (10) =
25 x 10 x 10 = 2500

(2) [150 - (3 • 4) (7 - 1)] [5 • (2 (4 + 1)) - 1] =
[150 - (12) (6)] [5 • (2 (5)) - 1] =
[150 - 72] [5 • (10) - 1] =
[78] [50 - 1] =
[78] [49] = 3822

Division

Division is another way of subtracting. For example, dividing 25 by 5 is the same as finding how many times we can take 5 away from 25. For example: One can subtract 5 from 25, five times.

25 - 5 = 20 (one)
20 - 5 = 15 (two)
15 - 5 = 10 (three)
10 - 5 = 5 (four)
5 - 5 = 0 (five)

By division:

Step 1: Five will not divide into two, but will divide into 25 at least five times.

$$\begin{array}{r} 5 \\ 5\overline{)\,25} \end{array}$$

Step 2: Multiply 5 x 5 and write the answer under 25. Remainder is zero. Answer is five even.

$$\begin{array}{r} 5 \\ 5\overline{)\,25} \\ \underline{25} \\ 0 \end{array}$$

Division problems can be written as follows:

(1) $\begin{array}{r} 5 \\ 5\overline{)\,25} \end{array}$

(2) $25 \div 5 = 5$

(3) $\frac{25}{5} = 5$

(4) $25/5 = 5$

In the preceding examples,

5 is the divisor
25 is the dividend
5 is the quotient

$$\begin{array}{rrl} & 5 & \text{(quotient)} \\ \text{(divisor)}\ 5 & \overline{)\,25} & \text{(dividend)} \end{array}$$

When one divides with numbers containing decimals, one should follow the rule stated below:

Rule 1: Move the decimal point of the divisor all the way to the right and the decimal point of the dividend the same number of places to the right. For example:

Divide 2.255 by 0.05

(1) Move the decimal point two places to the right in the divisor and the dividend.

$$.\underset{\curvearrowright}{05}\ \overline{)\ 2.\underset{\curvearrowright}{25}5}$$

(2) Five will not divide into 2 but will go into 22 about four times.

$$\begin{array}{rl} & 4 \\ 5 & \overline{)\,225.5} \end{array}$$

(3) Multiply 5 by 4 and subtract the answer from 22.

$$\begin{array}{rl} & 4 \\ 5 & \overline{)\,225.5} \\ & \underline{20} \\ & 2 \end{array}$$

(4) Bring down the five.

$$\begin{array}{rl} & 4 \\ 5 & \overline{)\,225.5} \\ & \underline{20} \\ & 25 \end{array}$$

(5) 5 will go into 25, five times. Note that the decimal in the quotient is placed directly over the decimal in the dividend.

$$\begin{array}{rl} & 45. \\ 5 & \overline{)\,225.5} \\ & \underline{20} \\ & 25 \end{array}$$

(6) Multiply 5 by 5 and subtract the answer from 25.

$$\begin{array}{rl} & 45. \\ 5 & \overline{)\,225.5} \\ & \underline{20} \\ & 25 \\ & \underline{25} \\ & 0 \end{array}$$

(7) Bring down the five. Five will go into 5 once.

$$\begin{array}{rr} & 45.1 \\ 5 & \overline{)\,225.5} \\ & \underline{20} \\ & 25 \\ & \underline{25} \\ & 05 \end{array}$$

(8) Multiply 5 by 1 and subtract the answer from 5.

$$\begin{array}{rr} & 45.1 \\ 5 & \overline{)\,225.1} \\ & \underline{20} \\ & 25 \\ & \underline{25} \\ & 05 \\ & \underline{5} \\ & 0 \end{array}$$

When solving a division problem, complete the indicated operations above and below the division line before dividing.

For example:

$$\left[\frac{50\ -\ (2)\quad(5)\ +\ \frac{15}{3}}{17\ -\ (2)\quad(3)\ -\ 1}\right] + \left[\frac{(6)\quad(3)}{9}\right] =$$

$$\left[\frac{50\ -\ 10\ +\ 5}{17\ -\ 6\ -\ 1}\right] + \left[\frac{18}{9}\right] =$$

$$\left[\frac{45}{10}\right] + \left[2\right] =$$

4.5 + 2 = 6.5

Fractions

A fraction is a part of a whole. When you cut a pipe into six equal parts and use five of those parts, you use $\frac{5}{6}$ of the pipe.

The terms of a fraction are the numerator and the denominator.

$$\frac{5}{6}\ \begin{array}{l}\text{Numerator}\\ \text{Denominator}\end{array}$$

A proper fraction is one whose value is less than one as $\frac{3}{4}$, $\frac{5}{8}$, $\frac{7}{10}$.

A mixed number contains a whole number and a fraction as $2\frac{3}{8}$, $5\frac{5}{6}$.

An improper fraction is one whose value is equal to one or greater than one.

In this type of fraction the numerator is equal to or greater than the denominator. For example:

Improper Fraction	Equal to
$\frac{4}{4}$	1
$\frac{8}{4}$	2
$\frac{5}{4}$	$1\frac{1}{4}$

To change an improper fraction to a whole or to a mixed number, divide the numerator by the denominator.

When there is a remainder, write it over the denominator. Reduce the fraction to its lowest terms.

For example $\frac{25}{5} = 5$ $\qquad$ $\frac{27}{5} = 5\frac{2}{5}$

In order to change a mixed number such as $5\frac{7}{8}$ to an improper fraction, one should follow these steps.

(1) Multiply the whole number by the denominator of the fraction.	(1) $5 \times 8 = 40$
(2) Add the product to the numerator.	(2) $40 + 7 = 47$
(3) Write the results over the denominator.	(3) $\frac{47}{8}$

Study the following example to see how to change a whole number such as five to an improper fraction.

(1)		$5 = \frac{?}{25}$
(2)	Step 1	$5 \times 25 = 125$
(3)	Step 2	$125 + 0 = 125$
(4)	Step 3	$\frac{125}{5}$

A fraction is in its lowest terms when there is no divisor that is common to both numerator and denominator as $\frac{2}{5}$, $\frac{5}{8}$.

A fraction can be reduced to its lowest terms by dividing the number that is contained exactly in both as $\frac{6}{8} = \frac{3}{4}$.

In other words, divide the numerator and denominator by the largest number that will divide evenly into both.

For example: $\frac{6}{8} = \frac{6 \div 2}{8 \div 2} = \frac{3}{4}$

Remember that the numerator and denominator can be divided or multiplied by the same number without changing the value of the fraction.

Sometimes it is necessary to reduce the fraction to its lowest terms by several trials. In this case, division continues until it can no longer be performed by a number larger than one.

For example:

$$\frac{400}{480} = \left[\frac{400 \div 4}{480 \div 4}\right] = \frac{100}{120} = \left[\frac{100 \div 10}{120 \div 10}\right] = \frac{10}{12} = \left[\frac{10 \div 2}{12 \div 2}\right] = \frac{5}{6}$$

To change a mixed number such as $7\frac{9}{4}$ to its simplest form:

1. Simplify the fraction $\frac{9}{4} = 2\frac{1}{4}$
2. Add the whole number to the result $7 + 2\frac{1}{4} = 9$

$9\frac{1}{4}$

A fraction can be changed to higher terms by multiplying both terms of the fraction by the same number.

For example:

$$\frac{2}{3} = \left[\frac{2 \times 2}{3 \times 2}\right] = \frac{4}{6} = \left[\frac{4 \times 3}{6 \times 3}\right] = \frac{12}{18} = \left[\frac{12 \times 2}{18 \times 2}\right] = \frac{24}{36}$$

SELF-TEST

1. Reduce $\frac{6}{8}$ to its lowest terms.	
a. In the fraction $\frac{6}{8}$ 6 is the ________ and 8 is the ________.	Numerator Denominator
b. To reduce the fraction to its lowest terms, we look for the ________ that is common to both the ________ and the ________.	Divisor Numerator Denominator
c. The largest number which can be divided into the numerator and denominator is ________.	two
d. By dividing both sides by the divisor, the fraction now looks like ________.	$\frac{3}{4}$
e. Can the fraction be reduced further?	no
2. Change the fraction $\frac{4}{5}$ to the highest term $\frac{x}{40}$.	
a. To find x we must first find what part of 40 is ________.	five
b. Five is what part of 40?	eight
c. The next step is to multiply ________ by eight.	four
d. x is ________.	32
e. The fraction $\frac{4}{5}$ therefore is expanded to ________.	$\frac{32}{40}$

ADDITION AND SUBTRACTION OF FRACTIONS

Fractions must have a common denominator before they can be added or subtracted. In adding or subtracting fractions, you simply add or subtract numerators.

For example: $\frac{4}{7} + \frac{3}{7} = \frac{7}{7} = 1 \qquad \frac{7}{9} - \frac{5}{9} = \frac{2}{9}$

If the denominators are not the same, they must be the same before addition or subtraction takes place. The numerator and denominator must be multiplied by the same number to change the form of a fraction.

For example: $\frac{2}{5} + \frac{6}{10} = \frac{2\ (2)}{5\ (2)} + \frac{6}{10} = \frac{4}{10} + \frac{6}{10} = \frac{10}{10} = 1$

$$\frac{1}{3} - \frac{2}{9} = \frac{1\ (3)}{3\ (3)} - \frac{2}{9} = \frac{3}{9} - \frac{2}{9} = \frac{1}{9}$$

Sometimes the denominators cannot be changed to one of the problem's existing denominators. In this case, the denominators must both be changed to the least common denominator. This means that the denominator is changed to the smallest number that each denominator will go into one or more times without a remainder.

For example: $\frac{2}{5} + \frac{1}{4}$

The lowest number that both 5 and 4 will go into is 20. 5 will go into 20, four times $\frac{20}{5} = 4$

4 will go into 20, five times $\frac{20}{4} = 5$

20 is the least common denominator

Therefore: $\frac{2 \times 4}{5 \times 4} + \frac{1 \times 5}{4 \times 5} = \frac{8}{20} + \frac{5}{20} = \frac{13}{20}$

SELF-TEST

1. Add $4\frac{1}{6} + 3\frac{1}{2}$

a.	To add these mixed numbers, we must first find the ________ ________ of $\frac{1}{6}$ and $\frac{1}{2}$.	Common Denominator
b.	The lowest number into which 6 and 2 will both divide into evenly is _________. This is the common denominator.	6
c.	What is X in the fraction $\frac{x}{6}$ when the fraction $\frac{1}{2}$ is changed to a higher term?	3
d.	Does $\frac{1}{6}$ have to be changed to a different fraction?	No
e.	$3\frac{1}{2}$ is therefore the same as 3 __________.	$\frac{3}{6}$
f.	The addition of the numerators is __________?	4
g.	Are the denominators added?	No
h.	The addition of the whole numbers is _________. (4 + 3 =)	7
i.	Therefore $4\frac{1}{6} + 3\frac{3}{6} =$ __________.	$7\frac{4}{6}$
j.	Is $7\frac{4}{6}$ the final answer?	No
k.	What must be done yet?	Reduce $\frac{4}{6}$ to its lowest terms
l.	Simplifying $\frac{4}{6}$ we get _________?	$\frac{2}{3}$
m.	The answer is _________?	$7\frac{2}{3}$

MULTIPLICATION AND DIVISION OF FRACTIONS

In multiplying fractions:

1. Change mixed numbers to improper fractions
2. Cancel whenever possible
3. Multiply numerators to find the numerator of the answer
4. Multiply denominators to find the denominator of the answer

Study the following example:

Multiply $2\frac{1}{10}$ by $\frac{5}{14}$

Step 1: $2\frac{1}{10} = \frac{21}{10}$

Step 2: In cancelling, look for a number in the numerator and the denominator that can be divided by the same number.

$$\frac{\overset{3}{\cancel{21}}}{\underset{2}{\cancel{10}}} \times \frac{\overset{1}{\cancel{5}}}{\underset{2}{\cancel{14}}} = \frac{3}{2} \times \frac{1}{2}$$

Step 3: $3 \times 1 = 3$

Step 4: $2 \times 2 = 4$

Answer: $\frac{3}{4}$

In dividing fractions -

1. Change mixed numbers to improper fractions.
2. Change the division sign to a multiplication sign.
3. Invert the divisor. The divisor always follows the division sign.
4. Follow the procedure for the multiplication of fractions.

Study the following example.

Divide $4\frac{5}{8}$ by $\frac{3}{8}$.

Step 1: $4\frac{5}{8} = \frac{37}{8}$

Step 2: $\frac{37}{8} \div \frac{3}{8} = \frac{37}{8} \times \frac{3}{8}$

Step 3: $\frac{37}{8} \times \frac{3}{8} = \frac{37}{8} \times \frac{8}{3}$

Step 4: $\frac{37}{8} \times \frac{8}{3} =$

$$\frac{37 \times 3}{8 \times 3} \times \frac{8 \times 8}{3 \times 8} = \frac{111}{24} \times \frac{64}{24}$$

$$\frac{111}{24} \times \frac{64}{24} = \frac{7104}{576}$$

$\frac{7104}{576} = 12\frac{192}{576}$ Since $7104 \div 576 = 12$ with remainder of 192.

Reducing $\frac{192}{576}$

$$\frac{192}{576} = \frac{192 \div 3}{576 \div 3} = \frac{64}{192}$$

$$\frac{64 \div 2}{192 \div 2} = \frac{32}{96} = \frac{32 \div 8}{96 \div 8} = \frac{4}{12} =$$

$$\frac{4 \div 4}{12 \div 4} = \frac{1}{3}$$

Answer: $12\frac{1}{3}$

SELF-TEST

1. Multiply $\frac{3}{8}$ by 4.

a. To multiply $\frac{3}{8}$ by 4, we first change __________ to a fraction.	4
b. This fraction is __________.	$\frac{4}{1}$
c. The problem now looks like __________ x _________.	$\frac{3}{8} \times \frac{4}{1}$
d. Multiplying the numerators, we get __________.	12
e. Multiplying the denominators, we get _________.	8
f. The fraction is now ________.	$\frac{12}{8}$
g. $\frac{12}{8}$ changes to _________, as a mixed number.	$1\frac{4}{8}$
h. If this the final answer?	No
i. Why?	$\frac{4}{8}$ can be further reduced
j. $\frac{4}{8}$ reduces to _________?	$\frac{1}{2}$
k. The answer is _________?	$1\frac{1}{2}$

DECIMALS

A decimal is a fraction whose denominator is 10, 100, 1000, etc. The value of the decimal is shown by the place it holds to the right of the decimal point. For example: $\frac{5}{10} = .5$; $\frac{5}{100} = .05$; $\frac{5}{1000} = .005$; $\frac{850}{10000} = .085$. When adding or subtracting decimals, put all decimal points in the same vertical line.

For example: Add .45, 7, .025, .05

$$\begin{array}{r} .450 \\ 7.000 \\ .025 \\ \underline{.05} \\ 7.525 \end{array}$$

To multiply decimals, find the total number of decimal places in the multiplicand and in the multiplier.

$$\begin{array}{rl} .23 & \text{Multiplicand} \\ \underline{\times\ .6} & \underline{\times\ \text{Multiplier}} \\ .138 & \text{Product} \end{array}$$

Counting from the right in the product, point off as many decimal places as there is in both multiplicand and multiplier. If necessary, add zeros to the left in the product. .13 x .4 = .052

To change a decimal to a fraction follow these steps:

(1) For the numerator, write the figures to the right of the decimal point.

(2) For the denominator, write 1 for the decimal point, and a zero for each decimal place.

For example: Change .068 to a fraction.

(1) 68

(2) 1000

Answer: $\frac{68}{1000} = \frac{17}{250}$

Dividing Decimals:

When the divisor is a whole number and dividend contains a decimal:

Place the decimal point in the quotient directly above the decimal point in the dividend.

For example: Divide .05 by 8

$$\begin{array}{r} .00625 \\ 8\,\overline{)\ .05} \end{array} \qquad\qquad \begin{array}{r} \text{Quotient} \\ \text{Divisor}\,\overline{)\ \text{Dividend}} \end{array}$$

NOTE: Add zeros if necessary to complete the division.

Changing fractions to decimals:

In changing a fraction to a decimal, divide the numerator by the denominator, but first write the decimal point to the right of the numerator, and add as many zeros as are needed to complete the division.

For example: $$\frac{5}{17} = \begin{array}{r} .2941176 \\ 17\,\overline{)\ 5.0000000} \end{array}$$

To divide when the divisor contains a decimal, follow these steps:

(1) Make sure you have as many decimal places in the dividend as you have in the divisor. If necessary, add a decimal point and zeros to the right of the dividend.

$$3.74\,\overline{)\ 23} \quad \text{becomes} \quad 3.74\,\overline{)\ 23.00}$$

(2) Make the divisor a whole number by moving the decimal point to the right of the last digit.

$$3.\underset{\curvearrowright}{74}\,\overline{)\ 23.00}$$

(3) Equalize this in the dividend by moving the decimal point as many places to the right as you have moved it in the divisor.

$$374\,\overline{)\ 23.\underset{\curvearrowright}{00}}$$

(4) Place the decimal point in the quotient directly above the decimal point in the dividend and divide.

$$374\,\overline{)\ 2300.}$$

(5) If necessary, add more zeros to complete this division.

$$\begin{array}{r} 6.149 \\ 374\,\overline{)\ 2300.000} \end{array}$$

SELF-TEST

1. Multiply 1.4 x .08	
a. Which number is the multiplicand?	1.4
the multiplier?	.08
b. How many decimal places are in the multiplicand? the multiplier?	1,2
c. The total number of decimal places is ________?	3
d. How many places to the left of the product do you count off?	3
e. Multiplying 1.4 x .08 the answer is ________?	.112

PRODUCTS AND FACTORS

A product is obtained by multiplying together two or more numbers: $8 = 4 \times 2$ (eight is the product). Each of the numbers multiplied is called a factor: 4 and 2 are factors of 8. A product is divisible by each of its factors: $8 \div 4 = 2$ and $8 \div 2 = 4$. So for each multiplication, there can be two divisions:

$8 = 4 \times 2$ (multiplication)

$8 = ? \times 2$ (division)

$8 = 4 \times ?$ (division)

$8 = 4 \times 2$ or Product = factor x factor

$$2 = \frac{8}{4} \qquad 4 = \frac{8}{2} \qquad \text{Or} \qquad \text{Factor} = \frac{\text{Product}}{\text{Factor}}$$

One can apply these rules to three types of problems.

Type 1 Find $\frac{1}{4}$ of 24

Product = Factor x Factor

$$P = \frac{1}{4} \times 24$$

$$= 6$$

Type 1 the product is missing, therefore the process is multiplication. 6 is the product.

NOTE: When one factor is less than 1 the product is less than the other factor.

Type 2 What part of 24 is 6?

Product = Factor x Factor

$$6 = F \times 24$$

Factor = Product ÷ Factor

$$= \frac{6}{24}$$

$$= \frac{1}{4}$$

In type 2 one of the factors is missing, therefore, the process is division.

Type 3. If $\frac{1}{4}$ of a number is 6, what is the number?

or $6 = \frac{1}{4}$ of what number?

Product = Factor x Factor

$$6 = \frac{1}{4} \times F$$

Factor = Product ÷ Factor

$$= 6 \div \frac{1}{4} \text{ or}$$

$$= 24$$

In type 3 one of the factors is missing, therefore, the process is division.

Calculators

As you can see it is much easier to work with decimals than fractions. Thanks to the availability and the low cost of electronic calculators almost any problem involving fractions can quickly be changed to one containing decimals. This is done by simply dividing the numerator by the denominator on the calculator and adding the resulting decimal to the whole number (if any) accompanying the fraction. For examply $5\frac{1}{17}$ can easily be converted to a decimal by first dividing 1 by 17 on the calculator. This gives a decimal of 0.059. This decimal is added to 5 to give 5.059.

Calculators are useful not only in converting fractions to decimals, but can also be used to speed up any water treatment plant problem calculation. Since each type of calculator is different, you should familiarize yourself with the instructions for the particular calculator you are using.

PERCENTAGE

Fractions express parts of a whole. These parts may be of various sizes such as halves, thirds, fourths, fifths, tenths, hundredths, etc. Decimals express parts of a whole. These parts may be tenths, hundredths, thousandths, etc. Percents are used to express parts of a whole, but these parts are limited to hundredths. Therefore, percent is another name for hundredths.

So 25% means 25 hundredths or .25.

To express a decimal as a percent:

1. Move the decimal point two places to the right.

$\underset{\curvearrowright}{.02}$ $\quad$ $\underset{\curvearrowright}{.20}$ $\quad$ $2\underset{\curvearrowright}{.00}$

2. Annex the percent sign (%)

2% $\quad$ 20% $\quad$ 200%

NOTE: Add zeros if necessary.

Study the following equivalents:

$.125 = .125 = 12.5\%$

$.125 = .12\frac{5}{10} = 12\ \frac{1}{2}\ \%$

$.0475 = .0475 = 4.75\%$

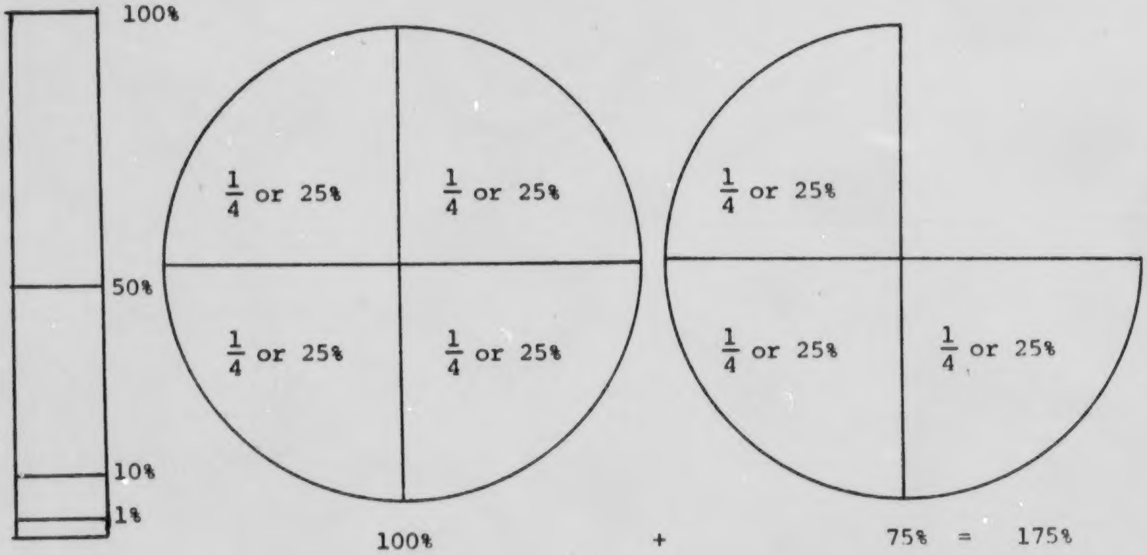
$.0475 = .04\ \frac{75}{100} = 4\ \frac{3}{4}\ \%$

$.03125 = .03125 = 3.125\%$

$.03125 = .03\ \frac{125}{1000} = 3\ \frac{1}{8}\ \%$

$.00125 = .00125 = .125\%$

$.00125 = .00\ \frac{125}{1000} = \frac{1}{8}\ \%$



$100\% \quad + \quad 75\% = 175\%$

$\frac{4}{4} \quad + \quad \frac{3}{4} = \frac{7}{4}$

$100\% = 1.00 \text{ or } 1$

$50\% = .5 \text{ or } \frac{1}{2}$

$10\% = .1 \text{ or } \frac{1}{10}$

$1\% = .01 \text{ or } \frac{1}{100}$

Percents less than 1% are decimals or fractional percents:

$\frac{1}{2}\% = \frac{1}{200} \text{ or } .5\%$

$\frac{3}{4}\% = \frac{3}{400} \text{ or } .75\%$

The value of 100 is one whole or one unit. Percents greater than 100% have a value greater than one unit.

$1.5 = 1.\underset{\curvearrowright}{50} = 150\%$ $\qquad 2 = 2.\underset{\curvearrowright}{00} = 200\%$

Expressing a Percent as a Decimal

1. Drop the percent sign $5\% = 5.$
2. Move the decimal point two places to the left $5. = \underset{\curvearrowleft}{05}. = .05$

NOTE: Prefix zeros when necessary

$104\% = 1.04 \qquad 4.25\% = .0425 \qquad \frac{1}{3}\% = .00\frac{1}{3} \qquad \frac{1}{2}\% = .00\frac{1}{2} \text{ or } .005$

Rounding Percents

.04518 = 4.518%

= 4.52% to the nearest hundredth of a percent

= 4.5% to the nearest tenth of a percent

= 5% to the nearest whole percent

Changing Fractions to Percents

1. A fraction may be changed to a decimal by dividing the numerator by its denominator.
2. A decimal may be changed to a percent by moving the decimal point two places to the right and adding the percent sign.

Note how the following fraction is changed to decimals and then to percents:

For example: $\frac{4}{5}$

Step 1: $\begin{array}{r} .8 \\ 5\,\overline{)\,4.0} \end{array}$

Step 2: .8 = .80 = 80%

Therefore: $\frac{4}{5}$ = .8 = 80%

Changing Percents to Fractions

1. A percent may be changed to a decimal by dropping the percent sign and moving the decimal point two places to the left.
2. A decimal of two places may be changed to a fraction by dropping the decimal point and dividing by 100.

Note how the following percents are changed to decimals and then to fractions:

Convert 6% to a fraction:

Step 1: 6. = 06. = .06

Step 2: .06 = 6 ÷ 100 or $\frac{6}{100}$

Reducing to lowest terms

$$\frac{6}{100} = \frac{3}{50}$$

Therefore: 6% = .06 = $\frac{3}{50}$

See is you can find the steps necessary to convert these percents to decimals than fractions.

225% = 2.25

2.25 = $2\,\frac{25}{100}$

$2\,\frac{25}{100} = 2\,\frac{1}{4}$

$\frac{1}{3}\,\% = .00\,\frac{1}{3}$

$.00\,\frac{1}{3} = \frac{1}{3} \div 100 = \frac{1}{3} \times \frac{1}{100} = \frac{1}{300}$

Percents in Problems

There are three types of problems involving percent. In doing percentage problems be careful of where you put the decimals.

Type 1 What percent one number is of another.

Read carefully to determine the correct fraction and then convert to a percentage.

Example 1. What percent is 7 of 14?

$$\frac{7}{14} = \frac{1}{2} = .5$$

$$.5 \times 100\% = 50\% \qquad (.5 = \underset{\curvearrowright}{.50} = 50\%)$$

Example 2. Eight is what percent of 24?

$$\frac{8}{24} = 0.333$$

$$0.333 \times 100\% = 33.3\% \qquad (0.333 = 0.\underset{\curvearrowright}{33}\,3 = 33.3\%)$$

Example 3. The amount of total solids entering the first of a series of settling tanks is 150 mg./l. The amount leaving this basin and going into the second tank is 75 mg./l. What percentage of the total solids is removed in the first basin? (NOTE: 150 - 75 is

$$\frac{150 - 75}{150} = \frac{75}{150} = 0.5 \text{ of the original load is:}$$

$$0.5 \times 100\% = 50\% \text{ removal} \qquad (0.5 = \underset{\curvearrowright}{.50} = 50\%)$$

$$\text{Therefore \% removal} = \frac{(\text{In} - \text{Out})}{\text{In}} \times 100\%$$

Type 2 Percent of a given number.

The percent is expressed as a decimal and then multiplied times the other number.

Example 1. Find 8% of 36.

$0.08 \times 36 = 2.88$

Example 2. Find 75% of 12.

$.75 \times 12 = 9$

Example 3. What is the weight of suspended solids in a ton (2000 lbs.) of raw water containing 2% solids and 98% water:

NOTE: 2% solids means that there is 2 lbs. of solids for every 100 lbs. of water.

2000 x .02 = 40 lbs. of suspended solids

Type 3 Finding a number when a given percent of it is known.

In this type of problem, convert the percentage to a decimal and divide by the decimal.

Example 1. If 15% of a number is 21, what is the number?

$$\frac{21}{0.15} = 140$$

To check the answer, find what is 15% of 140.

.15 x 140 = 21

Example 2. 18 is 75% of what amount?

$$\frac{18}{.75} = 24$$

Example 3. Percent removal of suspended solids in a clarifier is 40%. If 85 mg./l. are removed, what is the influent suspended solids?

$$\text{Influent solids} = \frac{85 \text{ mg./l.}}{.40} = 212.5 \text{ mg./l.}$$

Check: Original load x % removal = load removal

212.5 mg./l. x 0.40 = 85 mg./l.

RATIO AND PROPORTION

When one compares two numbers of the same units, one is finding the ratio of the numbers. For example, 2 ml. compared to 5 ml. Ratios can be written as fractions, $\frac{2}{5}$ or as 2:5 (read: the ratio of 2 to 5).

When one equates ratios, one is doing proportions. For example, $\frac{5}{10}$ is equal to $\frac{1}{2}$. The form a proportion is written in is usually $\frac{a}{b} = \frac{c}{d}$, or a:b = c:d (read: a is to b as c is to d). To solve the proportion $\frac{a}{b} = \frac{c}{d}$, we multiply diagonally across $\frac{a}{b} \times \frac{c}{d}$. When we do this a x d - b x c. This is called cross multiplication. For example:

$$\frac{5}{10} = \frac{1}{2} \qquad 10 \times 1 = 5 \times 2 \qquad 10 = 10$$

If one knows one complete ratio and one term of the second ratio, one can find the unknown term of the second ratio.

For example: Find c in the proportion $\frac{5}{10} = \frac{c}{2}$

$$10 \times c = 5 \times 2$$

$$\frac{\cancel{10} \times c}{\cancel{10}} = \frac{5 \times 2}{10}$$ Divide both sides of the equation by 10.

$$c = \frac{10}{10}$$

$$c = 1$$

Example 2: If certain parts of a machine cost \$9.00 a dozen, how much would four parts cost?

We know that 12 parts cost \$9.00; 4 parts cost x cents. Therefore:

$$\frac{12}{9.00} = \frac{4}{x} \qquad \text{or} \qquad \frac{12}{4} = \frac{9.00}{x}$$

$$12 \times X = 9.00 \times 4 \qquad \text{or} \qquad 12 \times X = 9.00 \times 4$$

$$\frac{\cancel{12} \times X}{\cancel{12}} = \frac{9.00 \times 4}{12}$$

$$x = \frac{9.00 \times \cancel{4}^{\,1}}{\cancel{12}_{\,3}}$$

$$x = \frac{9.00}{3}$$

$$x = \$3.00 \text{ per 4 parts}$$

Example 3: If 5 lbs. of a chemical was added to 25 gallons of water to make a solution of a given strength, how many pounds would be added to 121 gallons to give the same concentration?

$$\frac{5 \text{ lbs.}}{25 \text{ gallons}} = \frac{x}{121 \text{ gallons}}$$

$$(x)\ (25 \text{ gals.}) = (5 \text{ lbs.})\ (121 \text{ gals.})$$

$$\frac{(x)\ (\cancel{25}\ \cancel{\text{gals.}})}{\cancel{25}\ \cancel{\text{gals.}}} = \frac{(5 \text{ lbs.})\ (121 \text{ gals.})}{25 \text{ gals.}}$$

$$x = \frac{(\overset{1}{\cancel{5}} \text{ lbs.})\ (121\ \cancel{\text{gals.}})}{\underset{5}{\cancel{25}\ \cancel{\text{gals.}}}}$$

$$x = \frac{121 \times 1 \text{ lb.}}{5}$$

$$x = 24.2 \text{ lbs.}$$

NOTE: Gallons is the numerator and denominator can be cancelled without changing the value of the solution.

Example 4: If four men do a job in nine hours, how long will it take six men to do the same job?

$$\frac{4 \text{ men}}{9 \text{ hrs}} = \frac{6 \text{ men}}{x \text{ hrs}}$$

$$(4 \text{ men})\ (x) = (6 \text{ men})\ (9 \text{ hrs})$$

$$\frac{(\cancel{4}\ \cancel{\text{men}})\ (x)}{\cancel{4}\ \cancel{\text{men}}} = \frac{(6 \text{ men})\ (9 \text{ hrs})}{4 \text{ men}}$$

$$x = \frac{{}^{3}(\cancel{6}\ \cancel{\text{men}})\ (9 \text{ hrs})}{{}_{2}\cancel{4}\ \cancel{\text{men}}}$$

$$x = \frac{(3)\ (9 \text{ hrs})}{2}$$

$$x = \frac{27 \text{ hrs}}{2}$$

$$x = 13.5 \text{ hrs}$$

Is this answer correct? Can it take more men more time to do the same job? In most cases the answer is no. This is an example of ratios which are inversely proportional to each other. In this case the products are constant not their ratios. The proper way to solve this problem is as follows:

$$4 \text{ men} \times 9 \text{ hours} = (6 \text{ men})\ (x \text{ hrs})$$

$$\frac{\overset{2}{\cancel{4}}\ \cancel{\text{men}} \times 9 \text{ hrs}}{\underset{3}{\cancel{6}}\ \cancel{\text{men}}} = x$$

$$\frac{18 \text{ hrs}}{3} = x$$

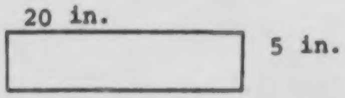
$$6 \text{ hrs} = x$$

AREAS

The perimeter of a figure is the distance around it. The perimeter of any figure is the sum of the length of its sides. For example, to determine the perimeter of a rectangle, one adds the length of one side to the length of the other side. To this number one adds the length of the two widths. One way of expressing this calculation is ln. + w. + ln. + w. One can express this equation as **2ln. x 2w. or 2(ln. x w.).**

Example 1.

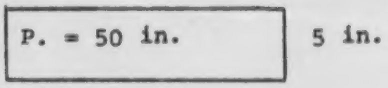
Find the perimeter of a rectangle which is 20 inches long and 5 inches wide.



$$\begin{aligned} P. &= 2\ (ln. + w.) \\ &= 2\ (20 + 5) \\ &= 2 \times 25 \\ &= 50 \text{ inches} \end{aligned}$$

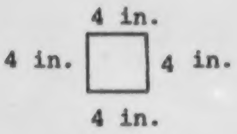
Example 2.

A rectangle with a perimeter of 50 inches is 5 inches wide. Find the length.



$$\begin{aligned} ln. &= \frac{P.}{2} - w. \\ &= \frac{50}{2} - 5 \\ &= 25 - 5 \\ &= 20 \text{ inches} \end{aligned}$$

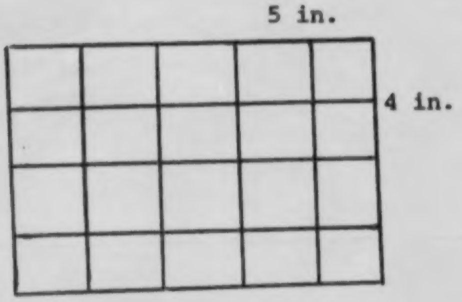
A square is a rectangle in which all sides are equal. The perimeter of a square is equal to the sum of the lengths of its sides. If a square is 4 inches long, the perimeter is 4 + 4 + 4 + 4 or 16 which may be expressed 4x side or 4s.



$$\begin{aligned} P. &= 4s. \\ &= 4 \times 4 \text{ in.} \\ &= 16 \end{aligned}$$

Area of Rectangle

The area of any figure is equal to the number of square units it contains. Study the rectangle below. It has been divided into square inches. Find how many square inches the figure contains.



Length or base if five inches.
Width or altitude is four inches.
There are four rows of square inches and each row contains five square inches.

Therefore, the number of square inches in the rectangle must equal 4 x 5 square inches or 20 square inches. The area of any rectangle may be found by multiplying the number of units in the length by the number of units in the width.

So the area of a rectangle may be expressed by the formula
A. = ln. x w. or A. = ln.w. where A. = Area, ln. = length, and w.=width.

$A = ln. \times w.$	$ln. = \frac{A.}{w.}$	$w. = \frac{A.}{ln.}$
$= 5 \times 4$	$= \frac{20}{4}$	$= \frac{20}{5}$
= 20 inches	= 5 inches	= 4 inches

THE LENGTH AND THE WIDTH MUST ALWAYS BE EXPRESSED IN THE SAME UNITS OF MEASUREMENT WHEN MULTIPLYING OR DIVIDING.

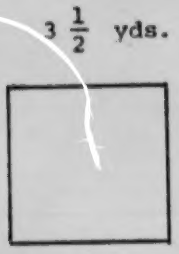
When both these dimensions are:
inches, the area will be square inches;
feet, the area will be square feet;
yards, the area will be square yards.

Area of a Square

Since the length of a square is the same as its width, the formula for finding the area of a square may be expressed A. = s. x s. instead of A. = ln.w. S. x S. is usually written $S.^2$, so A. = $S.^2$. The small number placed above and to the right of S. is called an exponent, and it means that the S. is to be multiplied by itself. So $S.^2$ = S. x S.

Example 1.

Find the number of square yards in a filter which measures $3\frac{1}{2}$ yards on a side.



$$A. = S.^2$$
$$= \frac{7}{2} \times \frac{7}{2}$$
$$= \frac{49}{4} = 12\frac{1}{4} \text{ sq. yds.}$$

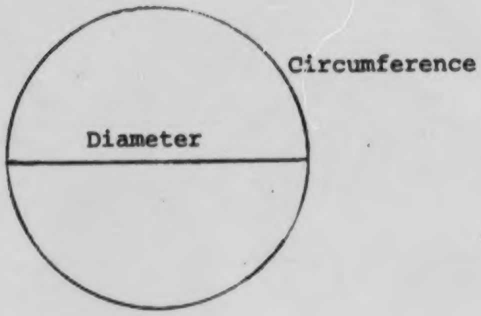
SELF-TEST

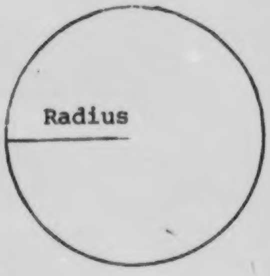
1. Find the number of yards in a building 300 yards long by 100 yards wide.

A.	What is the formula for finding the area of a rectangle?	A. = ln. x w.
B.	What is ln.?	300 yards
C.	What is w.?	100 yards
D.	Multiplying ln. x w., the answer is ______?	30,000
E.	What are the units?	square yards

THE CIRCLE

A circle is a portion of a plane bounded by a curved line, all points of which are equal distance from a point within called the center.





The circumference of a circle is the distance around it. The diameter of a circle is a straight line passing through the center, touching the circumference at both ends. The radius of a circle is a straight line from the center to the circumference. The radius is one half of the diameter.

If the diameter and circumference of several objects are measured such as a plate or a phonograph record, one finds that the circumference divided by the diameter is $3\frac{1}{7}$, (see below).

Object	Diameter	Circumference	$\frac{\text{Circumference}}{\text{Diameter}}$
Plate	7 inches	about 22 inches	$\frac{22}{7} = 3\frac{1}{7}$
Record	12 inches	about $37\frac{5}{7}$ inches	$\frac{37\frac{5}{7}}{12} = 3\frac{1}{7}$

From this we know that the circumference of a circle is about $3\frac{1}{7}$ times the diameter. The ratio of the circumference to the diameter is expressed by the Greek letter Pi, written π. The value of π is 3.1416.

$$\text{Circumference (c.)} = \pi \times \text{diameter (d.)}$$

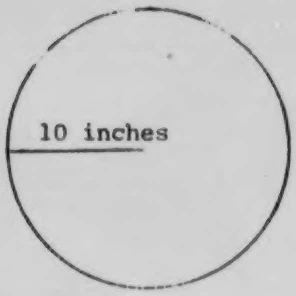
$$\text{c.} = \pi \text{ d.}$$

$$\text{d.} = \frac{\text{c.}}{\pi}$$

To find the radius, one takes $\frac{1}{2}$ the diameter or r. = $\frac{1}{2}$ d. To find the diameter one multiplies the radius by 2 or d. = 2r.

Study the following example:

How many feet are in the circumference of a circle having a radius of ten inches?

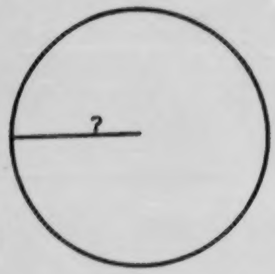


$$
\begin{aligned}
c. &= \pi d. \\
&= 3.1416 \times (2)\ (10 \text{ in.}) \\
&= 3.1416 \times (20 \text{ in.}) \\
&= 3.1416 \times (1.67 \text{ ft.})^{*} \\
&= 5.24 \text{ ft.}
\end{aligned}
$$

NOTE: The radius is given, so one must find the diameter (2) (10). *The radius is given in inches which must be changed to feet (multiplied by $\frac{1}{12}$).

SELF-TEST

1. Find the radius of a circle having a circumference of $24\frac{1}{7}$ ft.



$c. = 24\frac{1}{7}$

A.	What if the formula for finding the diameter of a circle?	$d. = \frac{c.}{\pi}$
B.	What is c.?	$24\frac{1}{7}$
C.	What is π?	3.1416
D.	Substituting the values of c. and π into the equation, the equation is __________?	$\frac{24\frac{1}{7}}{3.1416}$
E.	What is another way of expressing this equation _________ x _________?	24.1429 ÷ 3.1416
F.	Solving this equation, the answer is _______________.	7.6849
G.	This number is the ______________.	diameter
H.	To find the radius, one used the formula _____________.	$r. = \frac{1}{2} d.$
I.	Solving this equation, the radius of the circle is ____________.	3.8425

AREA OF A CIRCLE

Study the two figures below and note how the circle has been changed into a figure which looks somewhat like a rectangle. The area of the circle can be determined from the rectangular figure into which the circle has been changed.

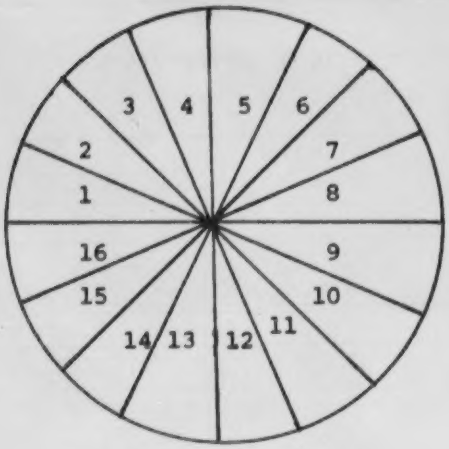


Figure 1

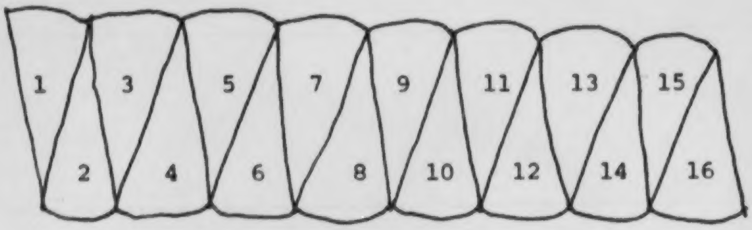


Figure 2

The circle has been divided into parts which have been fitted into one another to form Figure 2. If the circle had been divided into a greater number of parts, the base of the rectangle formed would look more like a straight line. The base of the new figure equals one half the circumference of the circle. The altitude of the new figure equals the radius of the circle.

Area of Figure 2. $= \text{base} \times \text{altitude}$

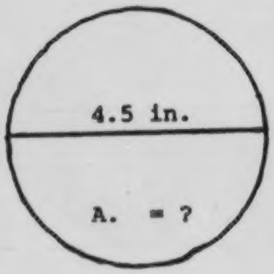
$= \frac{1}{2}$ circumference x r.

$= 2\pi$ d. x r. or $\frac{1}{\cancel{2}} \times \pi \cancel{2}r. \times r.$

Therefore, area of circle $= \pi r^2$.

Study the following example:

Find the area of a circle having a diameter of 4.5 inches.



$\text{d.} = 4.5$

$\text{r.} = \frac{1}{2} \times 4.5 = 2.25$

$\text{A.} = \pi\, \text{r.}^2$

$= 3.1416 \times 2.25 \times 2.25$

$= 15.9 \text{ sq.in.}$

Example 1. What is the area of a trickling filter with a 75 ft. radius?

$\text{A.} = \pi\, \text{r.}^2$

$= (3.1416) \ (75 \text{ ft.}) \ (75 \text{ ft.})$

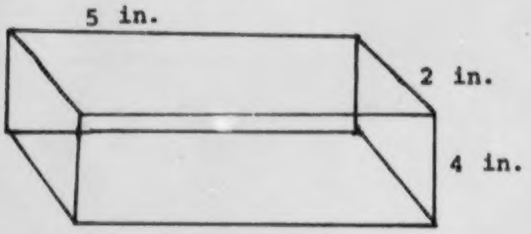
$= (3.1416) \ (5625 \text{ sq. ft.})$

$= 17671.5 \text{ sq. ft.}$

VOLUME

A Rectangular Solid

A rectangular solid has length, width, and height. It has six rectangular faces. A brick, a pound of butter, a block of granite are solids. An empty box, an empty carton are likewise regarded as solids. The volume of a solid is the number of cubic units it contains.



The figure represents a rectangular solid, 5 inches long, 2 inches wide, and 4 inches high. It is filled with 1 inch cubes. In the bottom layer there are 5 rows of 2 cubes each, that is 10 cubic inches. In 4 rows there are 4 x 10 or 40 cubic inches. Therefore, the total number of cubic inches in the solid is 40. 40 is the product of 5 x 2 x 4.

So V. = ln. x w. x h.

= ln.w.h..

V. = area of base x height
(Area of rectangle = ln. x w.)

Study the following example:

Find the volume of a rectangular chemical bin $10\frac{3}{4}$ inches long, $5\frac{1}{4}$ inches wide and $4\frac{1}{3}$ inches deep.

V. = ln. x w. x h.

$$V. = 10\frac{3}{4} \times 5\frac{1}{4} \times 4\frac{1}{3}$$

$$V. = \frac{43}{4} \times \frac{21}{4} \times \frac{13}{3}$$

$$= 244\frac{1}{2} \text{ cubic inches}$$

The Cube

A cube is a rectangular solid. Therefore its volume equals ln.w.h. Since all six faces of a cube are equal, ln., w., and h. are equal. Edge (e) may be substituted for ln., w., or h. Therefore,

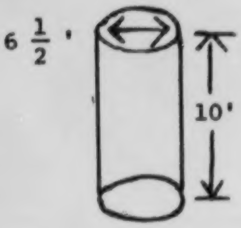
Volume of a cube = e. x e. x e. or $e.^3$

Volume = $e.^3$

The Cylinder

The volume of any regular solid with parallel bases is equal to the area of the base times the altitude. Therefore, Volume of a cylinder = Area of base x altitude. $V. = \pi r.^2 h.$

For example:



Find the volume of a holding tank having a diameter of $6\frac{1}{2}$ ft. and and height of 10 ft.

$V. = \pi r.^2 h.$

$= 3.1416 \times 3.25 \times 3.25 \times 10$

$= 331.8$ cu. ft.

THE USE OF VOLUMES IN WATERWORKS CALCULATIONS

We have already discussed how to calculate the volume of rectangles and cylinders. These formulas can be used to determine the volume of rectangular and circular tanks. In addition to these formulas, one should also know how to calculate the volume of a pipe and acre-feet of water. Study the following explanations and examples to understand how to figure these volumes.

Length of Pipe

To calculate the volume of a pipe, one multiplies the length times the area of the end section. Since the area of the end section (a circle) is equal to $\pi r.^2$ the formula for pipe volume is $\text{ln.} \times \pi r.^2$.

This as you will notice is the same formula as was used to calculate the volume of a cylinder. These are the same because a pipe is a cylinder.

Example: How many cubic inches are there in a pipe three feet long and ten inches wide?

$$\text{A.} = \text{ln.} \times \pi r.^2$$

$$= (3 \text{ foot} \times \frac{12 \text{ inches}}{1 \text{ foot}}) \times 3.1416 \times (\frac{1}{2} \times 10 \text{ in.}) \times (\frac{1}{2} \times 10 \text{ in.})$$

$$= 36 \text{ inches} \times 3.1416 \times (5 \text{ inches}) \times (5 \text{ inches})$$

$$= 2827.43 \text{ cubic inches}$$

Acre-Feet of Water

To calculate the acre-feet of water, one multiplies the surface areas times depth.

NOTE: When one finds the acre-feet of a body of water, one is finding the volume of water. Therefore, acre-feet means the same as volume.

For example:

How many acre-feet in a lake that covers 100 acres and is 9 feet deep?

V. = surface area x depth or $\pi r.^2 \times$ dp.

V. = 100 acres x 9 feet

V. = 900 acre feet

Volume - Gallons

So far we have calculated volume only in measurements of length e.g. cubic feet, cubic yards, etc. Let us see how volume can be calculated in gallons. The important conversion unit to remember in determining volume in gallons is: 1 cubic foot of water equals 7.48 gallons.

Study the following examples to see how the volume is calculated in gallons for a rectangular tank, circular tank, a foot of pipe and in 1 acre-foot of water.

Rectangular Tank

Gallons = length x width x depth x 7.48

Example:

How many gallons of water will a rectangular tank 35 feet x 25 feet by 15 feet hold?

$$V. = ln. \times w. \times dp. \times 7.48$$

$$= 35 \text{ feet} \times 25 \text{ feet} \times 15 \text{ feet} \times \frac{7.48 \text{ gallons}}{1 \text{ foot}^3}$$

$$= 98,175 \text{ gallons}$$

Circular Tank

Gallons = $\pi r.^2$ x depth x 7.48

Example:

How many gallons of water will a circular tank 30 feet in diameter and 20 feet deep hold?

$$A. = \pi r.^2 \times dp. \times 7.48$$

$$= 3.1416 \times 15' \times 15' \times 20' \times \frac{7.48 \text{ gallons}}{1 \text{ foot}^3}$$

$$= 105,746 \text{ gallons}$$

One Foot of Pipe

Gallons/foot of pipe = $\pi r.^2$ (ft.) x length x 7.48

Example:

How many gallons in a one foot section of twelve inch pipe?

gallons/foot of pipe = $\pi r.^2 \times l. \times 7.48$

$$= 3.1416 \times .5 \text{ foot} \times .5 \text{ foot} \times 1 \text{ foot} \times \frac{7.48 \text{ gal.}}{1 \text{ foot}^3}$$

$$= 5.875 \text{ gallons/foot}$$

One Acre Foot of Water

$$\text{Gallons/acre-foot of water} = \frac{43560\ \text{sq. ft.}}{1\ \text{acre}} \times \text{acre-foot} \times 7.48$$

(There are 43,560 square feet in one acre.)

Example:

How many gallons in two surface acres one foot deep?

$$\text{gallons/acre-foot} = \frac{43560\ \text{sq. ft.}}{1\ \text{acre}} \times 2\ \text{acre} \times 1\ \text{ft.} \times \frac{7.48\ \text{gal.}}{\text{ft.}^3}$$

$$= \frac{43560\ \cancel{\text{sq.}}\ \cancel{\text{ft.}}}{1\ \cancel{\text{acre}}} \times 2\ \cancel{\text{acre}} \times 1\ \cancel{\text{ft.}} \times \frac{7.48\ \text{gal.}}{\cancel{\text{ft.}^3}}$$

$$= 43560 \times 2 \times 1 \times 7.48\ \text{gal.}$$

$$= 651{,}657.6\ \text{gal.}$$

PROBLEM SOLVING

Problem solving is one of the major obstacles facing the beginning water treatment operator. In this section the necessary mathematical operations and logic needed to solve problems will be discussed. You will probably be amazed at how simple problem solving can be, once you have mastered the subject.

Division converts the denominator to unity is an important point to remember. For example, if five apples cost 45¢ and you wish to know the price of one apple, put the number of apples in the denominator, i.e., $\frac{\text{45¢}}{\text{5 apples}}$ or 9¢ for one apple. Put the cents in the denominator if you wish to know the number of apples you can purchase for 1¢, i.e., $\frac{\text{5 apples}}{\text{45¢}}$ or 0.11 apples for 1¢. Let us now do the same problem using chemicals instead of apples, since your intelligence has been insulted by doing second grade problems.

Example 1: If a minimum of 100.8 pounds of hydrochloric acid (HCl) is needed to react completely with 90.0 pounds of zinc (Zn), how much HCl is needed to react with one pound of Zn? The first thing we must ask is, what are we looking for? In this particular problem, it is how many pounds of HCl per one pound of Zn? 90.0 pounds of Zn is put in the denominator, if we use the same logic as before, i.e.,

$$\frac{\text{100.8 pounds of HCl}}{\text{90.8 pounds of Zn}} = \begin{array}{c}\text{1.12 pounds of HCl reacts}\\ \text{with one pound of Zn}\end{array}$$

Like the previous problem, this one is treated identically. If the problem asked how many pounds of Zn are needed to react with one pound of HCl, we would put 100.8 pounds of HCl in the denominator thus converting it to 1, i.e.,

$$\frac{\text{90.0 pounds of Zn}}{\text{100.8 pounds of HCl}} = \begin{array}{c}\text{.0893 pounds of Zn needed for one}\\ \text{pound of HCl}\end{array}$$

Division converts the denominator to unity is illustrated in these problems. Now for the next complication

Example 2: If 100.8 pounds of HCl are needed to react completely with 90.0 pounds of Zn, how many pounds of HCl are needed to react completely with 10.0 pounds of Zn?

What are we looking for? The amount of HCl necessary to react with 10.0 pounds of Zn is what is being sought. Ten times as much HCl will be needed for ten pounds of Zn, if we calculate the amount of HCl necessary to react with one pound of Zn (as above), i.e.,

$$(1) \quad \frac{100.8 \text{ lb. of HCl}}{90.0 \text{ lb. of Zn}} = \frac{1.12 \text{ lb. of HCl}}{1 \text{ lb. of Zn}}$$

$$(2) \quad \frac{1.12 \text{ lb. of HCl}}{1 \text{ lb. of Zn}} \times 10 \text{ lb. of Zn} = 11.2 \text{ lbs. of HCl}$$

We can combine these two steps into one as follows:

$$\frac{100.8 \text{ lb. of HCl}}{90.0 \cancel{\text{lb. of Zn}}} \times 10.0 \cancel{\text{lb. of Zn}} = 11.2 \text{ lbs. of HCl}$$

Note that the units "lb. of Zn" cancel leaving "lb. of HCl" on both sides of the equation, i.e.,

lb. of HCl = lb. of HCl

This check of units will show that the problem was set up in the right way.

SELF-TEST

1. If 100.8 pounds of HCl are needed to react completely with 90.0 pounds of Zn, how many pounds of Zn are needed to react with 21.0 pounds of HCl?

a.	First ask how many pounds of ________ react with 1 pound of ________.	Zn, HCl
b.	To obtain the above quantity ________ lb. of ________ are placed in the denominator to be converted to 1.	100.8, HCl
c.	________ lb. of ________ is placed in the numerator of this fraction.	90.0, Zn
d.	The fraction is ________.	$\frac{90.0 \text{ lb. of Zn}}{100.8 \text{ lb. of HCl}}$
e.	The above fraction is multiplied by ________ lb. of ________ to produce the answer.	21.0, HCl
f.	The answer is ________.	18.7 lb. of Zn

CONVERSION

This problem solving approach as outlined above can also be used for conversion of one unit of measurement to another. Conversion can be from the English system of measurement to the Metric system, from Metric to English or within either system.

Let us first look at the English system of measurement we are all familiar with.

Example 1: Convert $4\frac{1}{2}$ feet to inches. Basically the problem is how many inches are there in $4\frac{1}{2}$ feet. Since there are 12 inches per one foot.

$$\frac{12 \text{ inches}}{1 \text{ foot}} \times 4.5 \text{ feet} = 54 \text{ inches}$$

Example 2: Convert 54 inches to feet. Here we are trying to find how many feet are in 54 inches.

$$\frac{1 \text{ foot}}{12 \text{ inches}} \times 54 \text{ inches} = 4.5 \text{ feet}$$

The end of this section contains most of the units you will need to convert within the English system.

The pound (lb.), yard (yd.), and quart (qt.) are units of measurement in the English system. Each has its counterpart in the Metric system, a system based on units of ten. The meter (m.) is the basic unit of length, which is a little longer than a yard (39.37 inches to one meter). The table on p. 55 shows the prefixes which designate the different multiples of ten into which the meter is divided or combined. For example the millimeter is $\frac{1}{1000}$ of one m. The liter (l.) is the unit of volume in the Metric system and the gram (g.) is the unit of mass. The prefixes given in the above-mentioned table are combined with unit abbreviations. For example, the decimeter is abbreviated as dm., the centimeter is abbreviated as cm., the centiliter is abbreviated as cl., the milliliter is abbreviated as ml., and the kilogram is abbreviated as kg. The prefixes given in this table and the basic units should be memorized. Measurement is then simply expressed in the various units of the Metric system, e.g., 30 ml. = 03.0 cl. = 0.030 liter.

To convert from the Metric system to the English system, one uses these basic units:

1 in. = 2.54 cm.; 1 lb. = 454 g.; 1 quart = 0.946 liter

Using the problem solving approach as we did when we converted units in the English system, we can convert units from the English to the Metric system or from the Metric to the English system. Let us see how this is done in the two examples which follow:

Example 3: Convert 4 feet 3 inches to centimeters. The problem is simply how many centimeters are there in 51 inches? Since there are 2.54 cm. per one inch,

$$\frac{2.54 \text{ cm.}}{1 \text{ in.}} \times 51.0 \text{ in.} = 129.54 \text{ cm. or } 1.295 \text{ m.}$$

Example 4: Convert 45 cm. to inches. Basically we are trying to find the number of inches in one cm. Once we know this number, we can multiply it times 45 since there are 45 times as many inches in 45 cm. Since there are 2.54 cm. in 1 in., there are $\frac{1}{2.54}$ in. per cm. (Division converts the denominator to one). To solve this problem.

$$\frac{1 \text{ in.}}{2.54 \text{ cm.}} \times 45.0 \text{ cm.} = 17.72 \text{ in.}$$

TABLE 1

PREFIXES IN THE METRIC SYSTEM AND THEIR MEANING

Prefix	Meaning	Abbreviation
micro	$\frac{1}{1,000,000}$	mu (μ)
milli	$\frac{1}{1,000}$	m
centi	$\frac{1}{100}$	c
kilo	1000	k

SELF-TEST

1. Since 1.00 qt. = 0.946 liter, how many quarts are there in 50.0 liters?

a. The first question we ask is how many _________ in one _________?	qt., liter
b. This information is given by the fraction _________?	$\frac{1.00 \text{ qt.}}{0.946 \text{ liter}}$
c. To obtain the answer we multiply the above fraction by _________.	50 liters
d. _________ is the answer.	52.85 qts.
e. Since one quart contains 0.946 liters, should there be more or less than 50 quarts in 50 liters?	More

Milligrams per Liter

In laboratory and scientific work, milligrams per liter (mg./l.) is a unit of expression used to indicate very small concentrations. It is a weight/volume relationship.

As we mentioned in an earlier section the liter is a unit of volume. Volume can also be expressed in cubic meters since meters are a unit of length and the volume of a figure is the area of that figure's base times the height. Area of a square (cubic lengths, meters or feet) = ln. x w. x h.

Therefore, we can say 1000 liters = 1 cubic meter = 1,000,000 cu. centimeters. Since one cubic centimeter of water weighs one gram, 1 liter of water = 1000 grams or 1,000,000 milligrams.

$$\frac{1\text{ milligram}}{1\text{ liter}} = \frac{1\text{ milligram}}{1{,}000{,}000\text{ milligrams}} = \frac{1\text{ part}}{\text{million parts}} = \begin{array}{l}\text{1 part per}\\ \text{million (ppm)}\end{array}$$

Milligrams per liter (mg./l.) and parts per million (ppm) are often used interchangeably. Therefore, a concentration of 1 mg./l. or 1 ppm means that there is 1 part of substance by weight for every 1 million parts of water. A concentration of 20 mg./l. (20 ppm) would mean that there are 20 parts of substance per million parts of water.

CALCULATIONS FOR WATER TREATMENT PLANT OPERATORS

Up to this point, we have reviewed basic arithmetic and its application to a few water works problems. Now let us turn our attention to some specific water treatment plant calculations. While you study this section keep in mind the problem-solving technique presented previously. It will enhance your understanding of why the formulas work.

There are also some important conversion factors which you will need to know. These should be memorized so that you will be able to work these types of problems when you encounter them. The conversion factors are given in Table 2.

TABLE 2

8.34 pounds (lb.) = weight of one gallon of water

8.34 pounds per million gallons (lb./M.G.) = 1 milligram per liter (mg./l.) or 1 part per million (ppm)

17.12 mg./l. = one grain per gallon (gpg)

142.8 lbs./M.G. = one gpg

7000 grains = one lb.

325,850 gal. = one acre-foot of water

1440 minutes = one day

7.48 gallons = 1 cubic foot of water

Example 1: A plant with a capacity of four million pounds of water flowing through it a day keeps its chlorine concentration (100% chlorine) at 2.5 mg./l. How many lbs. of chemicals are used in a day?

$$2.5 \text{ mg./l.} \quad \text{or} \quad \frac{2.5 \text{ lbs. of chlorine (100\%)}}{1 \text{ million lbs. of water}}$$

lbs. of chemicals used = concentration x flow

$$= \frac{2.5 \text{ lbs.}}{\cancel{\text{million lbs.}}} \times \frac{4 \cancel{\text{ million lbs.}}}{\text{day}}$$

$$= 10 \text{ lbs. per day}$$

This problem is unusual in that flow is reported in pounds per day. Normally flow is reported in terms of gallons per minute or gallons per day. To convert flow figures to weight, one must use the conversion figure of one gallon of water equals 8.34 lbs.

Example 2: A plant draws 5 million gallons per day (mgd) from a lake which contains 150 mg./l. of suspended solids. How many pounds of suspended solids enter the plant per day?

Flow in lbs. per day = flow in million gal. per day (mgd) x 8.34 lbs. per gal.

$$= \frac{5 \text{ million } \cancel{\text{gal.}}}{\text{day}} \times \frac{8.34 \text{ lbs.}}{\cancel{\text{gal.}}}$$

$$= 41.7 \text{ million lbs./day*}$$

*NOTE: The "/" sign symbolizes the word per.

Suspended solids in lbs./day = Concentration in mg./l. x flow in lb./day

$$= \frac{150 \text{ mg.*}}{\text{million mg.}} \times \frac{41.7 \text{ million lbs.}}{\text{day}}$$

$$= 6{,}255 \text{ lbs./day}$$

*NOTE: $\frac{1 \text{ mg.}}{1{,}000{,}000 \text{ mgs.}} = \frac{1 \text{ lb.}}{1{,}000{,}000 \text{ lbs.}}$ These are identical ratios.

Therefore: lbs./day = Concentration in mg./l. x flow in mgd x 8.34 lbs./gal.

Example 3: If 4,450,000 gallons per day is being treated with 92.78 lbs. of 100% chlorine, what is the chlorine dose in ppm? (NOTE: 4,450,000 gal. = 4.45 M.G.)

$$\text{Concentration or Dose in ppm} = \frac{\text{lbs./day}}{\text{M.G. x } 8.34 \text{ lb./gal.}}$$

$$= \frac{92.78 \text{ lbs./day}}{4.45 \text{ M.G. x } 8.34 \text{ lbs./gal.}}$$

$$= \frac{92.78 \text{ lbs.}}{37.113 \text{ million lbs.}}$$

$$= 2.5 \text{ ppm or } 2.5 \text{ mg./l.}$$

Example 4: A pump delivers 400 gallons per minute of raw water to a settling tank. If this water averages 15 mg./l. of suspended solids, what is the total weight of suspended solids which could be deposited in the tank during a 24 hour day of continuous pumping?

(1) Flow in mgd = Flow in gal. per minute x 60 min./hr. x 24 hr./day

$$= \frac{400 \text{ gal.}}{\cancel{\text{min.}}} \times \frac{60 \cancel{\text{min.}}}{\cancel{\text{hr.}}} \times \frac{24 \cancel{\text{hr.}}}{\text{day}}$$

$$= 576{,}000 \text{ gal./day}$$

$$= 0.576 \text{ mgd}$$

(2) Weight of solids in lbs./day = Conc. in mg./l. x flow in mgd x 8.34 lbs./gal.

$$= \frac{15 \cancel{\text{mg.}}}{\cancel{\text{million mg.}}} \times \frac{0.576 \cancel{\text{M.G.}}}{\text{day}} \times \frac{8.34 \text{ lb.}}{\cancel{\text{gal.}}}$$

$$= 72.06 \text{ lbs. per day or about } 72 \text{ lbs./day}$$

Formulas to Remember

1. lbs. of chemicals = mgd x 8.34 lbs./gal. x dosage in mg./l.

2. dosage in mg./l. or ppm = $\frac{\text{lbs. of chemical fed}}{\text{mgd x 8.34 lbs./gal.}}$

lbs. of chemical if less than 100% pure =

$$\frac{\text{mgd x 8.34 lbs./gal. x dosage in mg./l. or ppm}}{\%}$$

ANOTHER APPROACH TO PROBLEM SOLVING

In order to solve any of the problems you have encountered so far, you have followed an unconscious process of identifying the problem, determining the kind of answer required and then collecting the information you need to solve the problem. You can use this process to help you solve problems in a way different from that mentioned earlier in this module.

The approach you take is to examine the problem and make a list of known and unknown information (Step 1). Sometimes a drawing or sketch will help to illustrate the problem. This drawing may help you to better see the unknowns, knowns and any additional information needed.

You can use either this approach or the one mentioned earlier to solve problems. It will depend on which approach you understand and find easier to use. Let us now illustrate the approach mentioned above with an example.

Example 1: What is the detention time in hours of a tank 10 feet deep, 25 feet wide, and 55 feet long, when the flow is 2.0 mgd?

KNOWN	UNKNOWN
Depth = 10 ft.	Detention time in hours
Width = 25 ft.	
Length = 55 ft.	
Flow = 2.0 mgd	

Now that the knowns and unknowns have been listed the next step is to select a formula that will give you the detention time (Step 2). Some useful treatment plant formulas are given near the end of this module.

The formula for finding the detention time is:

$$\text{Detention time in hours} = \frac{\text{Tank volume in gallons}}{\text{Flow in gallons/hour}}$$

The next step is to convert the known information to fit the terms in the formula (Step 3). For example, the flow is a known value but it is given in terms of million gallons per day. We need to know what the flow is in terms of gallons per hour.

First, we must change the term 2.0 million gallons per day to 2,000,000 gallons per day.

$$\begin{aligned}\text{Flow in gal. per day} &= 2.0 \text{ mgd}\\ &= 2{,}000{,}000 \text{ gal./day}\end{aligned}$$

The next thing we must find is what the flow is per hour. We know that there are 24 hrs./day so:

$$\text{Flow in gal./hr.} = \frac{2{,}000{,}000 \text{ gal.}}{\text{day}} = \frac{1 \text{ day}}{24 \text{ hrs.}}$$

$$= \frac{2{,}000{,}000 \text{ gal.}}{24 \text{ hours}}$$

$$= 83{,}333.33 \text{ gal./hour}$$

We now know what the flow is per hour.

The other part of the formula - capacity of tank in gallons - is unknown but from the information given in the formula, we can calculate what we need to know. The capacity or volume of the tank can be found from the formula: (V. - ln. x w. x h.

The volume of the tank = ln. x. w. x h.

= 55 ft. x 25 ft. x 10 ft.

= 13,750 cubic feet

We now have the folume of the tank in cubic feet; we need to have this volume in gallons. To do this a conversion factor is needed. Since there are 7.48 gallons per cubic foot, the conversion factor is 7.48 gal./cu.feet.

$$\text{Volume of tank in gallons} = 13{,}750 \text{ cubic ft.} \times \frac{7.48 \text{ gallons}}{1 \text{ cubic foot}}$$

$$= 102{,}850 \text{ gallons}$$

Therefore the volume of the tank in gallons is 102,850 gallons. We now have all the information we need to put in the formula to find detention time (Step 4).

$$\text{Detention time in hours} = \frac{\text{Tank volume in gallons}}{\text{Flow in gallons/hour}}$$

$$= \frac{102{,}850 \text{ gallons}}{83{,}333.33 \text{ gal./hr.}}$$

$$= 1.23 \text{ hours}$$

Remember that each term in a formula or a mathematical calculation must be of the correct units. For example, if the tank volume in the above problem were given in gallons, then 7.48 gal./cu.ft. would not be needed.

THE UNITS IN A FORMULA MUST ALWAYS BE CHECKED BEFORE ANY CALCULATIONS ARE PERFORMED. This will avoid mistakes.

Let us use this approach to problem-solving to find the following:

1. Dosage of chemical fed in grains per gallon (gpg) and in lbs. per million gallons.
2. Filtration Rate
3. Inches of rise per minute

In order to save space, the explanation of each step will be left out. If you do not understand what is happening in each step, go back and read pages 60 and 61 of this module.

Example 1: Find dosage in grains per gallon and lbs. per million gallons.

a. What is the dosage in grains per gallon, if 1500 lbs. of alum is added to 7,650,000 gallons of water per day?

Step 1. Writing down knowns and unknowns.

Known	Unknown
lbs. of alum - 1500 lbs./day	dosage in grains per gallon
Flow = 7,560,000 gal./day	

Step 2. Formula

$$\text{Grains per gallon fed} = \frac{\text{Grains of chemical fed/day}}{\text{Flow in gallons/day}}$$

Step 3. Convert known information to fit terms in the formula.

a. Convert lbs. of chemical fed to grains of chemical fed where 7,000 grains = 1 lb.

$$\text{Grains of chemicals} = \frac{1{,}500\ \cancel{\text{lbs}}.}{\text{day}} \times \frac{7{,}000\ \text{grains}}{1\ \cancel{\text{lb}}.}$$

$$= 10{,}500{,}000\ \text{grains/day}$$

Step 4. Solving the formula.

$$\text{Grains per gallon fed} = \frac{\text{Grains of chemical fed/day}}{\text{Flow in gal./day}}$$

$$= \frac{10{,}500{,}000\ \text{gr./day}}{7{,}650{,}000\ \text{gal./day}}$$

$$= 1.37\ \text{grains per gallon}$$

b. How many lbs./M.G. is the dosage, if 1500 lbs. of alum is added to 7,650,000 gallons of water per day?

Step 1.

Known	Unknown
lbs. of alum = 1,500 lbs.	Dosage in lbs./M.G.
Flow in gal./day = 7,650,000 gal./day	

Step 2. Dosage of chemical fed = $\frac{\text{lbs. of chemical fed/day}}{\text{mgd}}$

Step 3. Convert gal./day to mgd

$$\text{mgd} = \frac{7{,}650{,}000 \text{ gal./day}}{1{,}000{,}000}$$

$$= 7.65 \text{ mgd}$$

Step 4. Dosage = $\frac{\text{lbs. of chemical fed/day}}{\text{mgd}}$

$$= \frac{1{,}500 \text{ lbs./}\cancel{\text{day}}}{7.65 \text{ mg}\cancel{\text{d}}}$$

$$= 196.078 \text{ lbs./M.G. or } 196.078 \text{ ppm}$$

Example 2. Calculating filtering rates.

If 900 gallons per minute (gpm) are filtered through a sand filter 15 feet square, what is the filtration rate (gal./min./sq.ft.)

Step 1.

Known	Unknown
Number of gallons filtered per minute = 900 gpm	Filtration rate in gal./min./sq.ft.
Side of filter = 15 feet	

Step 2. Filtration rate = $\frac{\text{gpm filtered}}{\text{sq.ft. of filter area}}$ or $\frac{\text{gpm filtered}}{\text{area of filter}}$

Step 3. Find area of filter.

$$\text{A.} = \text{s.}^2$$

$$= (15 \text{ ft.}) \quad (15 \text{ ft.})$$

$$= 225 \text{ sq.ft.}$$

Step 4. Filtration rate = $\frac{\text{gpm filtered}}{\text{area}}$

$$= \frac{900 \text{ gpm}}{225 \text{ sq.ft.}}$$

$$= 4 \text{ gal. per min. per sq.ft.}$$

Example 3. Inches of rise per minute.

How many gallons per minute (gpm) is used to rinse a filter 15 feet square if the inches of rise per minute is 40 inches per minute?

Step 1.

Known	Unknown
Side of filter = 15 feet	Gallons per minute of water used to rinse filter
Inches of rise per minute = 40 inches per minute	

Step 2. gpm = Inches of rinse per minute x gal. per inch passing through filter

Step 3. Find gal. per inch of water passing through filter.

a. Find area of filter.

$$\text{A.} = \text{s.}^2$$

$$= (15\ \text{ft.})\ \ (15\ \text{ft.})$$

$$= 225\ \text{sq.ft.}$$

b. Find the number of gallons passing through the filter when 7.48 gal. is equal to 1 cubic foot.

$$\text{gal.} = 225\ \cancel{\text{ft.}} \times \cancel{\text{ft.}} \times \frac{7.48\ \text{gal.}}{1\ \text{ft.} \times \cancel{\text{ft.}} \times \cancel{\text{ft.}}}$$

$$= 1683\ \text{gal./ft.}$$

c. Convert ft. to inches when 12 inches = 1 foot.

$$\text{gal./in.} = \frac{1683\ \text{gal.}}{\cancel{\text{ft.}}} \times \frac{1\ \cancel{\text{ft.}}}{12\ \text{in.}}$$

$$= 140.25\ \text{gal./in.}$$

Step 4. gpm = Inches of rinse per minute x gal. per in.

$$= \frac{40\ \cancel{\text{in.}}}{\text{minute}} \times \frac{140.25\ \text{gal.}}{1\ \cancel{\text{in.}}}$$

$$= 5{,}610\ \text{gal. per min.}$$

SELF-TEST

1. If a tank holds 25,000 gallons and the flow is 250,000 gallons per day, what is the detention time in hours?

a. What are we looking for?	Detention time in hours
b. What is the volume?	25,000 gallons
c. What is the flow?	250,000 gal.per day
d. Remembering that division converts the denominator to unity, what is the equation for finding how long 25,000 gal. of water held in the tank?	$\frac{\text{25,000 gal.}}{\text{250,000 gal.per day}}$
e. The answer to this equation is _________?	.1
f. The units are ________?	days
g. To convert .1 day to hours one _________ by 24 hours per day.	multiplies
h. How many hours are there in .1 day?	2.4 hours
i. Is this the answer?	Yes

NOTE: The equation for finding the detention time in hours is:

$$\frac{\text{Capacity of tank}}{\text{Gallons per day}} \times 24 = \text{Detention time in hours}$$

SUMMARY OF USEFUL EQUATIONS

1. Perimeter of a rectangle = 2 (ln. + w.)

2. Area of a rectangle = ln. x w.

3. Area of a square = $s.^2$

4. Area of a circle = $\pi r.^2$
   a. Circumference of a circle = π d.
   b. Diameter = $\frac{c.}{\pi}$
   c. Diameter = 2(radius)   Radius = $\frac{1}{2}$ diameter

5. Volume of a rectangle = ln. x w. x h.

6. Volume of cube = $s.^3$

7. Volume of a cylinder = $\pi r.^2$ h.

8. Volume of a pipe = $\pi r.^2$ h.

9. Acre-feet = surface area x h. or $\pi r.^2$ h. or ln. x w. x h.

10. Volume in gallons of rectangle = ln. x w. x h. x 7.48

11. Volume in gallons of cylinder = $\pi r.^2$ x h. x 7.48

12. Volume in gallons of pipe = $\pi r.^2$ x length x 7.48

} measurements should be in feet

13. Gallons per acre-ft. = 43,560 x acre-ft. x 7.48

14. lbs. of chemicals required = M.G. x 8.34 x dosage in mg./l.

15. lbs. of chemicals required (less than 100% pure chemicals) =

$$\frac{\text{M.G. x 8.34 x dosage in mg./l.}}{\%}$$

16. lbs. of chemicals required = M.G. x 142.8 x dosage in gpg

17. dosage in mg./l. or ppm = $\frac{\text{lbs. of chemical fed}}{\text{M.G. x 8.34}}$

18. dosage in gpg = $\frac{\text{lbs. of chemical fed}}{\text{M.G. x 142.8}}$

19. Grains per gallon fed = $\frac{\text{Pounds of chemicals fed x 7000}}{\text{Million gallons}}$

SUMMARY OF USEFUL EQUATIONS (Continued)

20. Filtration rate = $\dfrac{\text{gpm filtered/sq.ft.}}{\text{square feet of filter area}}$

a. gallons per minute = $\dfrac{\text{in.of rise per minute x sq.ft.filter area x 7.48}}{12}$

21. Detention time in minutes = $\dfrac{\text{Capacity of tank}}{\text{Gallons per minute}}$

22. Detention time in hours = $\dfrac{\text{Capacity of tank}}{\text{Gallons per hour}}$

NOTE: M.G. as used in these formulas means the number of million gallons e.g. 7.0 million gallons, 52.0 million gallons, etc.

Million gallons as used in these formulas means that the number of gallons treated is written out in terms of 1,000,000 gal. e.g. 7,000,000 gallons, 52,000,000 gallons, etc.

USEFUL ABBREVIATIONS

c = centi

cm. = centimeter

cu. = cubic

d = deca

ft. = foot (')

g. = grams

gal. = gallons

gpd = gallons per day

gpg = grains per gallon

gpm = gallons per minute

gr. = grains

in. = inches (")

k = kilo

km. = kilometer

l. = liter

lbs. = pounds

ln. = length

dp. = depth

Special Abbreviation- used only in this Module

m. = meter

M.G. = million gallons

mgd = million gallons per day

mi. = mile

mg./l. = milligrams per liter

ppm = parts per million

qt. = quart

sq. = square

μ = micron

CONVERSION FACTORS

1 acre-foot = 43,560 cu.ft.
1 acre-foot = 325,850 gal.
1 acre = 43,560 sq.ft.
1 acre = 4,840 sq.yds.

1 centigram (cg.) = 0.01 g.
1 centimeter (cm.) = .3937 in.
1 cm. = 10 mm.

1 cubic centimeter (cc.) = .00003531 cu.ft.
1 cc. = .001 l.
1 cc. = .06102 cu.in.

1 cu.yd. = 27 cu.ft.
1 cu.yd. = 46,660 cu.in.
1 cu.yd. = 202 gal.
1 cu.yd. = 764.6 l.
1 cu.yd. = 808 qt.

1 decigram = .1 g.

1 ft. = 30.48 cm.
1 ft. = 12 in.
1 ft. = .3048 m.
1 ft. = .33 yd.
1 ft./minute = .01667 ft./sec.
1 ft./minute = .01136 mi./hr.
1 ft./sec. = 1.097 km./hr.
1 ft./sec. = .6818 mi./hr.
1 ft./sec. = .01136 mi./min.

1 cu.ft. = 28,320 cc.
1 cu.ft. = 1,728 cu.in.
1 cu.ft. = .03704 cu.yd.
1 cu.ft. = 28.32 l.
1 cu.ft. = 29.92 qt.
1 cu.ft. water = 7.48 gal.
1 cu.ft. water = 62.4 lbs.
1 cu.ft./min. = .1247 gal./sec.
1 cu.ft./min. = .472 l./sec.
1 cu.ft./min. = 62.4 lb. water/min.
1 cu.ft./sec. = 646,300 gal./day
1 cu.ft./sec. = 448.8 gal./min.
1 cu.ft./sec. = 7.48 gal./sec.
1 cu.in. = 16.39 cu.cm.
1 cu.in. = .0005787 cu.ft.
1 cu.in. = .00002143 cu.yds.
1 cu.in. = .004329 gal.
1 cu.in. = .01639 l.
1 cu.in. = .0173 qt.

1 gallon = .1337 cu.ft.
1 gallon = 231 cu.in.
1 gallon = .004951 cu.yds.
1 gallon = 3.785 l.
1 gallon = 4.0 qts.
1 gallon water = 8.34 lbs. water
1 gallon water/min. = 192.5 cu.ft./day
1 gallon water/min. = .002228 cu.ft./sec.
1 gallon water/min. = 8.021 cu.ft./hr.
1 gallon water/min. = 0.6308 l./day
1 gallon water/min. = 1440 gal./day

1 millimeter = .0394 in.
1 milligram/liter = .0584 gr./gal.
1 milligram/liter = 1.0 ppm
1 milligram/liter = 8.34 lb./M.G.
1 million gallons = 3.07 acre-ft.
1 M.G./day = 1.55 cu.ft./sec.
1 M.G./day = 695 gal./min.

1 ounce = 1.805 cu.in.
1 ounce = 0.0625 lbs.
1 ounce = .0296 l.

parts per million = .0584 gr./gal.
parts per million = 1.0 mg./l.
parts per million = 8.34 lb./M.G.

1 pound = 7,000 gr.
1 pound = 454 g.
1 pound water = .01602 cu.ft.
1 pound water = 27.7 cu.in.
1 pound water = .12 gal.
1 pound water/min. = .000267 cu.ft./sec.

CONVERSION FACTORS (Continued)

1 grain/gallon = 17.12 mg./l.
1 grain/gallon = 142.86 lb./M.G.
1 grain = .000143 lbs.
1 gram = 15.43 gr.
1 gram = 1,000 mg.
1 gram = .002205 lbs.

1 gram/liter = 58.42 gr./gal.
1 gram/liter = 8.34 lbs./1,000 gal.
1 gram/liter = .0624 lbs./cu.ft.

1 in. = 2.54 cm.
1 in. = .083 ft.
1 in. = 254,000 μ

1 kilogram = 2.2 lb.
1 kilogram = 1,000 g.

1 liter = 0.0353 cu.ft.
1 liter = 61.02 cu.in.
1 liter = .264 gal.
1 liter = 1.06 qt.
1 liter = 1,000 ml.
1 liter/min. = .000589 cu.ft.
1 liter/min. = .0044 gal./sec.

1 meter = 100 cm.
1 meter = 1000 mm.
1 meter = 3.281 ft.
1 meter = .001 km.

1 micron = .001 mm.
1 micron = 0.000039 in.

1 quart = .25 gallon
1 quart = .946 l.
1 quart = 2 pts.

1 square centimeter = .001076 sq.ft.
1 square centimeter = .155 sq.in.
1 square foot = .00002296 acres
1 square foot = 929 sq.cm.
1 square foot = 144 sq.in.
1 square inch = .00694 sq.ft.
1 square mile = 640 acres
1 square millimeter = .00155 sq.in.

1 yard = 91.44 cm.
1 yard = 3 ft.
1 yard = .9144 m.

1 mile = 5,280 ft.
1 mile = 1.609 km.
1 mile = 1609.3 m.
1 mile = 1,760 yds.

PRACTICE PROBLEMS

Fractions

I. Reduce to lowest terms:

1. $\frac{21}{49} =$ $\frac{24}{28} =$ $\frac{56}{64} =$

2. $\frac{63}{81} =$ $\frac{14}{42} =$ $\frac{30}{45} =$

3. $\frac{27}{81} =$ $\frac{48}{60} =$ $\frac{24}{72} =$

4. $\frac{72}{96} =$ $\frac{48}{72} =$ $\frac{19}{38} =$

II. Change to higher terms:

1. $\frac{7}{9} = \frac{\quad}{54}$ $\frac{6}{7} = \frac{\quad}{56}$ $\frac{9}{10} = \frac{\quad}{50}$

2. $\frac{5}{6} = \frac{\quad}{48}$ $\frac{7}{15} = \frac{\quad}{60}$ $\frac{3}{20} = \frac{\quad}{80}$

3. $\frac{1}{6} = \frac{\quad}{18} = \frac{\quad}{24} = \frac{\quad}{54}$

4. $\frac{4}{5} = \frac{\quad}{60} = \frac{\quad}{45} = \frac{\quad}{35}$

III. Change to whole or to a mixed number:

1. $\frac{19}{9} =$ $\frac{54}{9} =$ $\frac{35}{8} =$

2. $\frac{58}{6} =$ $\frac{76}{8} =$ $\frac{50}{9} =$

3. $\frac{32}{8} =$ $\frac{42}{5} =$ $\frac{81}{9} =$

4. $\frac{59}{7} =$ $\frac{76}{9} =$ $\frac{44}{7} =$

IV. Change to improper fractions:

1. $4\frac{3}{5} =$ $9\frac{1}{8} =$ $5\frac{3}{10} =$

2. $6\frac{7}{8} =$ $4\frac{7}{11} =$ $2\frac{9}{13} =$

3. $1\frac{1}{25} =$ $8\frac{4}{7} =$ $2\frac{5}{12} =$

V. **Change the whole number to an improper fraction:**

1. $3 = \frac{\_}{4}$ $\qquad 4 = \frac{\_}{5}$ $\qquad 5 = \frac{\_}{9}$

2. $4 = \frac{\_}{4}$ $\qquad 9 = \frac{\_}{6}$ $\qquad 5 = \frac{\_}{10}$

3. $12 = \frac{\_}{2}$ $\qquad 2 = \frac{\_}{24}$ $\qquad 10 = \frac{\_}{12}$

VI. **Change to Simplest Form:**

1. $7\frac{10}{10} =$ $\qquad 8\frac{9}{9} =$ $\qquad 5\frac{24}{24} =$

2. $8\frac{10}{9} =$ $\qquad 5\frac{7}{6} =$ $\qquad 8\frac{9}{7} =$

3. $7\frac{16}{12} =$ $\qquad 2\frac{24}{18} =$ $\qquad 6\frac{40}{32} =$

4. $3\frac{4}{5} =$ $\qquad 4\frac{15}{12} =$ $\qquad 8\frac{35}{40} =$

5. $7\frac{27}{24} =$ $\qquad 9\frac{15}{15} =$ $\qquad 3\frac{25}{20} =$

VII. **Addition and Subtraction of Fractions:**

Add:

1.
$$\begin{array}{r} \frac{1}{8} \\ + \frac{5}{8} \\ \hline \end{array} \qquad \begin{array}{r} \frac{7}{8} \\ + \frac{3}{8} \\ \hline \end{array} \qquad \begin{array}{r} \frac{5}{6} \\ + \frac{1}{6} \\ \hline \end{array}$$

2.
$$\begin{array}{r} 7\frac{1}{4} \\ + 8\frac{3}{4} \\ \hline \end{array} \qquad \begin{array}{r} 9\frac{2}{5} \\ + 6\frac{3}{5} \\ \hline \end{array} \qquad \begin{array}{r} 4\frac{5}{9} \\ + 3\frac{4}{9} \\ \hline \end{array}$$

3.
$$\begin{array}{r} 10\frac{3}{4} \\ + 5\frac{3}{4} \\ \hline \end{array} \qquad \begin{array}{r} 7\frac{13}{24} \\ + 8\frac{17}{24} \\ \hline \end{array} \qquad \begin{array}{r} 7\frac{17}{20} \\ + 4\frac{13}{20} \\ \hline \end{array}$$

4.
$$\begin{array}{r} 7\frac{3}{5} \\ + \frac{4}{5} \\ \hline \end{array} \qquad \begin{array}{r} \frac{8}{9} \\ + 4\frac{7}{9} \\ \hline \end{array} \qquad \begin{array}{r} 9\frac{7}{10} \\ + \frac{9}{10} \\ \hline \end{array}$$

5.
$$\begin{array}{r} 6\frac{3}{4} \\ + 9\frac{5}{8} \\ \hline \end{array} \qquad \begin{array}{r} 7\frac{5}{12} \\ + 8\frac{5}{6} \\ \hline \end{array} \qquad \begin{array}{r} 9\frac{17}{30} \\ + 8\frac{7}{10} \\ \hline \end{array}$$

6.
$$\begin{array}{rrr} 5\frac{5}{6} & 6\frac{1}{2} & \frac{7}{24} \\ 6\frac{2}{3} & 10\frac{5}{8} & \frac{7}{12} \\ +\ 3\frac{7}{12} & +\ \frac{3}{4} & +\ 3\ \frac{5}{6} \\ \hline \end{array}$$

7.
$$\begin{array}{rrrr} \frac{7}{8} & \frac{5}{6} & \frac{5}{9} & \frac{15}{16} \\ +\ \frac{1}{6} & +\ \frac{7}{9} & +\ \frac{7}{12} & +\ \frac{11}{12} \\ \hline \end{array}$$

8. $6\frac{4}{9} + 10\frac{5}{12} + 18\frac{1}{6} + 14\frac{5}{8} + 5\frac{1}{4} =$

9. $9\frac{1}{2} + 6\frac{3}{4} + 3\frac{7}{8} + 14\frac{5}{6} + 8\frac{2}{3} =$

Subtract:

1.
$$\begin{array}{rrrrrr} \frac{4}{9} & \frac{7}{12} & \frac{11}{24} & \frac{1}{2} & \frac{9}{10} & \frac{2}{3} \\ -\ \frac{1}{3} & -\ \frac{1}{6} & -\ \frac{3}{8} & -\ \frac{1}{4} & -\ \frac{2}{5} & -\ \frac{5}{12} \\ \hline \end{array}$$

2.
$$\begin{array}{rrrrrr} \frac{5}{9} & \frac{9}{10} & \frac{11}{24} & \frac{5}{6} & \frac{2}{3} & \frac{1}{2} \\ -\ \frac{1}{6} & -\ \frac{4}{15} & -\ \frac{3}{16} & -\ \frac{5}{8} & -\ \frac{2}{7} & -\ \frac{4}{9} \\ \hline \end{array}$$

3.
$$\begin{array}{rrrrr} 2\frac{1}{2} & 9\frac{7}{24} & 8\frac{7}{24} & 6 & 8\ \frac{2}{3} \\ -\ 1\frac{1}{4} & -3\ \frac{1}{8} & -\ 6\ \frac{1}{6} & -\ 4\frac{3}{5} & -\ 4 \\ \hline \end{array}$$

4.
$$\begin{array}{rrrrr} 8\frac{1}{3} & 7 & 6\frac{1}{10} & 9 & 5\ \frac{4}{14} \\ -\ \frac{3}{5} & -\ 1\frac{4}{7} & -\ \frac{9}{10} & -\ \frac{7}{8} & -\ \frac{11}{14} \\ \hline \end{array}$$

5. $8\frac{1}{6} - 6\frac{5}{9} =$ $\qquad$ $4\frac{3}{5} - 3\frac{6}{7} =$

6. From $9\frac{5}{8}$ take $7\frac{1}{3}$ $\qquad$ Take $2\frac{4}{9}$ from $7\frac{1}{4}$

7. From $3\frac{2}{9}$ take $1\frac{7}{12}$ Take $2\frac{5}{6}$ from $8\frac{1}{4}$

Find the answers:

1. $\frac{1}{2} + \frac{5}{12} - \frac{2}{3} =$ $\frac{8}{9} - \frac{1}{3} + \frac{4}{9} =$ $\frac{7}{9} + \frac{1}{18} - \frac{5}{6} =$

2. $\frac{7}{9} + \frac{2}{3} + \frac{9}{10} =$ $\frac{3}{4} - \frac{3}{8} + \frac{1}{2} =$ $\frac{4}{5} - \frac{3}{10} + \frac{5}{8} =$

3. $\frac{2}{3} - \frac{5}{12} + \frac{3}{20} =$ $\frac{3}{5} + \frac{3}{20} - \frac{1}{4} =$ $\frac{12}{15} + \frac{1}{3} - \frac{1}{5} =$

4. From the sum of $\frac{3}{4}$ and $\frac{1}{6}$ take $\frac{5}{8}$.

5. From 8 take the difference between $4\frac{5}{18}$ and $2\frac{7}{12}$.

VIII. Multiplication and Division of Fractions

Multiply:

1. $\frac{5}{9} \times 27 =$ $\frac{9}{10} \times 15 =$ $\frac{3}{8} \times 32 =$

2. $\frac{4}{15} \times 9 =$ $12 \times \frac{7}{8} =$ $10 \times \frac{5}{8} =$

3. $6 \times \frac{5}{12} =$ $12 \times \frac{5}{24} =$ $27 \times \frac{4}{21} =$

4. $\frac{5}{6} \times \frac{3}{10} =$ $\frac{9}{10} \times \frac{5}{12} =$ $\frac{24}{25} \times \frac{5}{8} =$

5. $3\frac{1}{9} \times \frac{6}{7} =$ $6\frac{2}{9} \times \frac{3}{8} =$ $\frac{20}{21} \times 2\frac{4}{7} =$

6. $12 \times \frac{3}{8} =$ $3 \times \frac{5}{12} =$ $\frac{4}{5} \times 35 =$

7. $6\frac{1}{4} \times 1\frac{1}{10} \times 7\frac{1}{2} \times 3\frac{1}{9} =$

8. $5\frac{1}{3} \times 3\frac{3}{4} \times 2\frac{1}{12} \times 4\frac{1}{5} =$

9. $6\frac{2}{5} \times 15 \times \frac{7}{8} \times 2\frac{5}{6} =$

10. $\frac{14}{15} \times 2\frac{1}{24} \times 5\frac{5}{7} \times 1 =$

Divide:

1. $1\frac{1}{5} \div \frac{3}{4} =$ $\quad$ $5\frac{4}{7} \div \frac{3}{14} =$ $\quad$ $8\frac{1}{6} \div \frac{7}{12} =$
2. $\frac{4}{9} \div \frac{7}{15} =$ $\quad$ $\frac{5}{6} \div \frac{7}{8} =$ $\quad$ $\frac{14}{15} \div \frac{14}{15} =$
3. $6 \div \frac{2}{3} =$ $\quad$ $\frac{5}{8} \div 10 =$ $\quad$ $\frac{32}{35} \div 16 =$
4. $4\frac{1}{2} \div 2\frac{5}{8} =$ $\quad$ $8\frac{1}{3} \div 7\frac{1}{7} =$ $\quad$ $5\frac{4}{9} \div 3\frac{1}{3} =$
5. $\frac{9}{10} \times \frac{8}{9} \div \frac{7}{30} =$ $\quad$ $3\frac{1}{5} \times \frac{7}{12} \div 2\frac{1}{3} =$
6. $10 \div \frac{5}{6} =$ $\quad$ $9 \div \frac{3}{8} =$ $\quad$ $35 \div \frac{7}{10} =$
7. $\frac{5}{8} \div 15 =$ $\quad$ $\frac{9}{10} \div 6 =$ $\quad$ $\frac{7}{12} \div 14 =$
8. $\frac{3}{4} \div \frac{9}{8} =$ $\quad$ $\frac{9}{14} \div \frac{6}{7} =$ $\quad$ $\frac{21}{28} \div \frac{3}{7} =$

IX. Decimals:

Add:

1. .4, 2.05, 1.6, .403
2. 3.57, 35.7, .357, .0357
3. 5.942, 87.04, 0.367, .0451

Find the answers:

1. From 8.1 take 4.073.
2. Take .405 from .45.
3. What is the difference between .09 and .07?

Multiply:

1.	$\begin{array}{r} .014 \\ \underline{.8} \end{array}$	$\begin{array}{r} 1.4 \\ \underline{.08} \end{array}$	$\begin{array}{r} 8.6 \\ \underline{.35} \end{array}$
2.	$\begin{array}{r} 34.8 \\ \underline{.92} \end{array}$	$\begin{array}{r} 628.3 \\ \underline{.35} \end{array}$	$\begin{array}{r} 83.62 \\ \underline{9.2} \end{array}$
3.	$\begin{array}{r} 9.035 \\ \underline{.84} \end{array}$	$\begin{array}{r} 5.391 \\ \underline{3.8} \end{array}$	$\begin{array}{r} .8927 \\ \underline{70} \end{array}$
4.	.0009 by 900	135.47 by 702	
5.	700.05 by 405	9700 by 5.04	

X. Express as fractions in their lowest terms:

1.	0.125	.0075	0.625
2.	0.0625	0.375	.0375
3.	0.955	0.0875	0.0065

Divide:

1.	$9\overline{)\ .27}$	$7\overline{)\ .42}$	$4\overline{)\ .05}$
2.	$32\overline{)\ .12}$	$24\overline{)\ 93.2}$	$75\overline{)\ 25.5}$
3.	$24\overline{)\ 17.28}$	$56\overline{)\ 45.08}$	$72\overline{)\ .252}$
4.	$.08\overline{)\ 64}$	$.7\overline{)\ 42}$	$.06\overline{)\ 192}$
5.	$.04\overline{)\ 35}$	$.08\overline{)\ 3}$	$.16\overline{)\ 1}$

6. 6.4) 48   13.2) 198   .04) 3.4

7. .018) 10.8   .06) .288   .16) 4.8

8. .23) 3.381   .24) 1.632   .48) 1.2

9. .025) 78.8   2.7) 4.374   .07) 1.9684

Change to Decimals:

$\frac{1}{8}$ = $\frac{1}{20}$ = $\frac{4}{5}$ = $\frac{3}{4}$ = $\frac{19}{20}$ = $\frac{12}{25}$ =

Solve the following problems:

1. What is $\frac{4}{6}$ of 24?
2. What is $\frac{5}{9}$ of 72?
3. Find .875 of 56.
4. How many times 12 is 27?
5. At 260 mph, how far will a plane travel in $3\frac{1}{2}$ hours?
6. If a pilot averages 320 mph, how long will it take to go 1440 miles?

XI. Percentage

Express as percent:

1. .0625   .0375   .01125

2. .06375   .04875   .0275

3. .065   .051   .009

4. 3.25   1.42   5.04

5. 4.05   3.09   6

Express as Decimals:

1. 12%   62.5% $66\frac{2}{3}$%

2. $16\frac{2}{3}$% $14\frac{2}{7}$%   37.5%

3. 3.75%   12.5% $3\frac{1}{3}$%

4. 106% $\frac{1}{3}$%   .5%

5. 115% $\frac{1}{6}$%   160%

Expr Express as Decimals and then as Percents:

1. $\frac{3}{10}$ = $\frac{3}{5}$ = $\frac{5}{8}$ =
2. $\frac{1}{20}$ = $\frac{3}{50}$ = $\frac{1}{6}$ =
3. $\frac{2}{3}$ = $\frac{1}{16}$ = $\frac{1}{12}$ =
4. $\frac{1}{9}$ = $\frac{3}{32}$ = $\frac{1}{200}$ =
5. $\frac{1}{250}$ = $\frac{1}{80}$ = $\frac{1}{400}$ =

Express as Decimals and then as Fractions in their Lowest Form:

1. 60% $6\frac{1}{4}$% 90% 175%
2. $12\frac{1}{2}$% $8\frac{1}{3}$% $14\frac{2}{7}$% 5%
3. $9\frac{1}{11}$% $\frac{4}{5}$% 8% $66\frac{2}{3}$%

XII. Find the Missing Dimension:

	Perimeter	Length	Width
1.	______ ft.	12 ft.	11 ft.
2.	______ ft.	24 ft.	19 ft.
3.	______ ft.	3 ft. 8 in.	$12\frac{1}{2}$ ft.
4.	______ ft.	$1\frac{2}{3}$ yd.	$1\frac{1}{6}$ ft.
5.	42 ft.	______ ft.	5 ft.
6.	6 yd.	6 ft.	______ ft.
7.	17 ft.	______ ft.	$1\frac{1}{16}$ ft.
8.	100 ft.	27 ft.	______ ft.

9. How many feet of molding will be needed to go around a room 12 feet wide and 5 yards long?

10. How many feet are there in the perimeter of a rectangular lot 97 ft. 6 in. deep with a frontage of $9\frac{1}{2}$ yards.

XIII. Find the AREA of the following Squares:

1. S. = 9 in. S. = 1 ft. 2 in. S. = 8 yd.

2. S. = 2 ft. 2 in. S. = 6 yd. 2 ft. S. = 4.6 yd.

3. What is the cost of 3 square pieces of glass 20 inches long at $.75 a square foot?

4. If the perimeter of a square table is 12 yards, what is the area?

5. The perimeter of a square wall is 110 feet. If a man paints both sides of it, over how many square yards does he paint?

Find the Missing Dimension:

	Area	Length	Width
1.	______ sq. ft.	4 yd.	10 ft.
2.	______ sq. ft.	8 ft.	$1\frac{1}{3}$ yd.
3.	$6\frac{1}{2}$ acres	______ yd.	$16\frac{1}{4}$ yd.

4. How many tiles each 5 inches by 3 inches are needed for a floor 15 by 10 ft.?

5. The area of a platform is 112 square yards. If the length is 28 yards, what is the width?

6. At $.07 a square yard, find the cost of a varnishing a floor 36 feet long and 24 feet wide.

7. A rectangular building lot 80 feet long contains 3600 square feet. What was the width of the lot?

XIV. The Circle

Find the missing Dimension:

1. d. = 6 in. r. = r. = 5 in. d. =

2. d. = 28 in. c. = r. = $1\frac{3}{4}$ ft. d. =

3. d. = 7 in. r. = d. = 35 in. c. =

4. A circular tank has a radius of $52\frac{1}{2}$ feet. If a man puts steel reinforcements around 2 different places on the tank, how many feet has he placed of steel?

5. How much longer is the circumference of a circle having a diameter of $3\frac{1}{2}$ feet than one with a radius of $1\frac{1}{2}$ feet?

Find the Area of the following when:

1. r. = $3\frac{1}{2}$ in. d. = 14 in.
2. r. = $2\frac{1}{3}$ ft. d. = 3 yd.
3. d. = 21 ft. r. = $1\frac{2}{5}$ yd.
4. A tree stump has a diameter of 35 inches. What is its area?
5. Find the area and circumference of a circle which has a diameter of 6 feet.

XV. Volume

Find the Volume of the following Rectangular Solids:

	Length	Width	Height
1.	10 in.	8 in.	5 in.
2.	8 in.	$4\frac{1}{2}$ in.	$4\frac{1}{6}$ in.
3.	$5\frac{1}{3}$ ft.	$3\frac{1}{2}$ ft.	$2\frac{5}{8}$ ft.
4.	8 in.	8 in.	8 in.
5.	$2\frac{1}{2}$ in.	$2\frac{1}{2}$ in.	$2\frac{1}{2}$ in.
6.	6 ft.	6 ft.	6 ft.

7. Find the number of cubic feet of space in a storage bin 12 feet long, $4\frac{1}{2}$ feet wide and $3\frac{1}{2}$ feet high.
8. Find the volume of a cubical box $1\frac{1}{2}$ feet on an edge.
9. How many cubes 2 inches long are equivalent in volume to a 6 in. cube?
10. The volume of a 6 inch cube is how many times as large as the volume of a 3 in. cube?

Find the Volume of the following Cylinders:

	Volume (Gallon)	Diameter	Height
1.		8 inches	$10\frac{1}{2}$ inches
2.		$3\frac{1}{3}$ ft.	$8\frac{2}{5}$ ft.
3.		9 ft.	$3\frac{5}{6}$ ft.

4. A water storage tank has a height of 6 feet and a diameter of $4\frac{2}{3}$ feet. Find its capacity.

5. An oil drum is $3\frac{3}{5}$ feet high and $2\frac{1}{3}$ feet in diameter. What is its capacity?

6. A tank with a diameter of 10 feet is filled to 15 feet. It will contain approximately how many gallons?

7. How many gallons of water is contained in 75 feet of 9-inch pipe?

8. What is the capacity of six hundred feet of 6-inch main?

9. A well has a diameter of five feet and is one hundred and seventy-five feet deep. How many acre-feet are there? (In cubic feet and in gallons)

10. Fill in the blanks:

	Acre-feet	Surface area	Depth
a.	________ cu. ft.	250 ft.^{2}	10 ft.
b.	________ gallons	1000 ft.^{2}	15 ft.
c.	________ cu. ft.	500 sq. ft.	25 ft.
d.	________ gallons	15 ft. in diameter	5 ft.

Using the problem-solving technique described in this module, solve the following:

1. If a car travels 100 miles in 5 hours, how far would it travel, at the same rate, in 9 hours?

2. There are 9 gugs in 3 gits. How many gugs are there in 13 gits?

3. In chemical reaction 15.6 g. of copper (Cu) combine with 3.9 g. of sulfur (S). How many grams of Cu combine with 30 grams of S?

4. A pump delivers 250 gallons per minute. How many hours must it operate to pump 150,000 gallons into the distribution system?

5. A five thousand gallon tank is filled in 5 hours. What is the pumping rate in gallons per minute?

Carry out the following Conversions:

1.	$4\frac{1}{2}$ ft. to inches	$\frac{3}{4}$ ft. to inches
2.	$6\frac{2}{3}$ yd. to feet	$6\frac{1}{9}$ yd. to inches
3.	54 in. to feet	90 in. to yards
4.	30 cm. to m.	52 m. to cm.
5.	1,220 m. to km.	1 liter to ml.
6.	20 g. to kg.	.5 g. to mg.
7.	25 ft. to cm.	950 g. to lb.
8.	5 qt. to liters	7 ft. 5 in. to m.
9.	2 oz. to mg.	45 lb. to kg.

10. How much larger (express as a fraction of a quart) is 12 liters than 12 quarts?

11. Seven thousand gallons of water per filter are used to wash four filters, which filtered a total of 2,000,000 gallons of water between washing. What is the percent of wash water?

12. A treatment plant pumps 250 gpm to a village of 150 people during a nine hour work day. What is the plant output in mgd? What is per capita consumption?

XVI. Calculations for Water Treatment Plant Operators

1. A gallon of water weighs how many pounds?
2. A cubic foot of water weighs how many pounds?
3. A gallon of water contains how many cubic feet?
4. 500 gpm is equal to how many mgd?
5. One cubic foot of water contains how many gallons?
6. What do these abbreviations mean?
   a. gpd
   b. gpg
   c. M.G.
   d. mg.
   e. ppm
   f. mgd
   g. gpm
   h. l.
   i. m.
7. One ppm is equal to how many mg./l.? lbs./M.G.? grains/gallon?
8. Convert the following:
   a. 50 lbs./M.G. to ppm
   b. 4 grains per gallon to ppm
   c. 2 lbs./M.G. to ppm
   d. 10 mg./l. to ppm
   e. 4 ppm to mg./l.
   f. 10 ppm to lbs./M.G.
   g. 25 ppm to grains per gallon
9. If water contains 4 ppm of Cu, it means that there are:
   a. 33.36 gallons of Cu in 1 million gallons of water.
   b. 33.36 pounds of Cu in 1 million gallons of water.
   c. 33.36 pound of Cu in 1 million pounds of water.
   d. 33.36 milligrams in 1 million pounds of water.
10. Is there 1 ppm of chlorine in the 1 M.G. of water if it was treated with 8.34 pounds of chlorine?
11. If water is treated with 5 grains of alum per gallon, how many ppm is this?
12. How many pounds of chlorine is necessary to treat 15 M.G. of water to have 2.0 ppm residual chlorine?
13. How many pounds of a chemical is needed in one million gallons of water to equal one ppm?
14. If there was found to be 10 milligrams per liter of a substance in a water supply, how many ppm is there?
15. 17.12 mg./l. contains how many grains/gallon? ppm? lbs./M.G.?

16. 500 ppm is equal to how many mg./l.? cg./l.? dg./l.? g./l.?

17. Determine the weight of carbon dioxide contained in 1,000,000 gallons of water, if the water was analyzed to have ten ppm of carbon dioxide.

18. How much chlorine is needed to chlorinate 600,000 gallons of water per day to obtain a rate of 0.7 ppm?

19. How many ppm chlorine is found in the water to which chlorine has been fed at a rate of 50 pounds per 24 hours? The flow was 5 mgd. (Hint: How many pounds are needed to treat one million gallons?)

20. If a water treatment plant treats 2,500,000 gallons of water per day, calculate the following in ppm and gpg.

Weight of Chemical	ppm	gpg
312 lbs. of alum		
150 lbs. of lime		
20 lbs. of carbon		
15 lbs. of chlorine		

21. What is the filtration rate of a filter sixteen feet by eighteen feet that is operated at a rate of two gallons per square foot per minute?

22. At 3.5 gallons per square foot per minute, what is the rate of filtration of a filter five feet square?

23. How many gallons of wash water are used to clean a filter bed fifteen feet in length and seven feet in depth? The filter is washed for five minutes and during the washing period the water rises 25 inches per minute.

24. A filter 20 square feet is rinsed with 5 gallons per sq. ft. per minute. What will be the inches of rise per minute?

25. Fill in the blanks:

Inches of rise/minute	gpm	Filter length	Width
a. ______	300	10 ft.	12 ft.
b. 30	___	20 ft.	15 ft.
c. ______	500	20 ft.	20 ft.
d. 27	___	15 ft.	15 ft.

26. Fill in the blanks:

Filtration Rate	gpm	Filter length	Width
a. ______ gpm/sq.ft.	600	18 ft.	15 ft.
b. ______ gpm/sq.ft.	400	18 $\frac{1}{2}$ ft.	10 ft. 5 in.
c. ______ gpm/sq.ft.	300	25.5 ft.	252 in.
d. ______ gpm/sq.ft.	200	16 ft.	21 ft.

27. Fill in the blanks:

Pounds of Chemical (100% Pure)	M.G.	Dosage
a. ______	2.5	17.1 mb./l.
b. ______	3.0	142.86 lb./M.G.
c. ______	$1\frac{1}{4}$	3 gpg
d. ______	2.0	25.68 mg./l.
e. ______ (75% Pure)	2.5	17.12 mg./l.
f. ______ (90% Pure)	3.0	142.86 lb./M.G.
g. ______ (85% Pure)	$1\frac{1}{4}$	3 gpg
h. ______ (60% Pure)	2.0	26=68 mg./l.

28. How many pounds of chlorine is needed to treat 2,500,000 gallons of water to obtain a 1.5 gpg dosage?

29. A plant treating 2,000 gallons per minute during a ten hour period will require how many pounds of alum to obtain a dosage of 1.5 gpg?

30. A 25 feet wide, 150 feet long and 10 feet deep settling basin has a retention time of what, if the daily water usage (24 hrs.) is 2,000,000 gallons? The water flows through the plant at a uniform rate. (Give the answer in hours and in minutes.)

31. What is the detention period of a settling basin 125 feet long, 90 feet wide and 25 feet deep used to treat 5,000 gallons of water per minute?

32. Fill in the blanks:

Detention Period	Capacity of tank			gpd
	length	width	depth	
a. ______minutes	15 ft.	10 ft.	5 ft.	2,500,000
b. ______hours	15 ft.	10 ft.	5 ft.	2,500,000
c. ______minutes	$20\frac{1}{2}$ ft.	$15\frac{3}{4}$ ft.	10 ft.	3,000,000
d. ______hours	25.7 ft.	20.2 ft.	15 ft.	5,000,000

33. Fill in the blanks:

Dosage	Pounds of Chemical Fed	M.G.
a. ______gpg	2000	5.0
b. ______mg./l.	300	10
c. ______gpg	500	25.25
d. ______mg./l.	2000	2.5
e. ______gpg	1500	20.1
f. ______mg./l.	1500	20.1

ANSWERS

Fractions

I. Reduce to lowest terms

1.	$\frac{3}{7}$	$\frac{6}{7}$	$\frac{7}{8}$
2.	$\frac{7}{9}$	$\frac{1}{3}$	$\frac{2}{3}$
3.	$\frac{1}{3}$	$\frac{4}{5}$	$\frac{1}{3}$
4.	$\frac{3}{4}$	$\frac{2}{3}$	$\frac{1}{2}$

II. Change to higher terms

1.	42	48	45
2.	40	28	12

3. 3, 4, 9

4. 48, 36, 28

III. Change to whole or to a mixed number

1.	$2\frac{1}{9}$	6	$4\frac{3}{8}$
2.	$9\frac{2}{3}$	$9\frac{1}{2}$	$5\frac{5}{9}$
3.	4	$8\frac{2}{5}$	9
4.	$8\frac{3}{7}$	$8\frac{4}{9}$	$6\frac{2}{7}$

IV. Change to improper fractions

1.	$\frac{23}{5}$	$\frac{73}{8}$	$\frac{53}{10}$
2.	$\frac{55}{8}$	$\frac{51}{11}$	$\frac{35}{13}$
3.	$\frac{26}{25}$	$\frac{60}{7}$	$\frac{29}{12}$

V. Change the whole number to an improper fraction

1. $\frac{12}{4}$ $\frac{20}{5}$ $\frac{45}{9}$
2. $\frac{16}{4}$ $\frac{54}{6}$ $\frac{50}{10}$
3. $\frac{24}{2}$ $\frac{48}{24}$ $\frac{120}{12}$

VI. Change to Simplest Form

1. 8 9 6
2. $9\frac{1}{9}$ $6\frac{1}{6}$ $9\frac{2}{7}$
3. $8\frac{1}{3}$ $3\frac{1}{3}$ $7\frac{1}{4}$
4. $3\frac{4}{5}$ $5\frac{1}{4}$ $8\frac{7}{8}$
5. $8\frac{1}{8}$ 10 $4\frac{1}{4}$

VII. Addition and Subtraction of Fractions

Add:

1. $\frac{6}{8} = \frac{3}{4}$ $\frac{10}{8} = \frac{5}{4} = 1\frac{1}{4}$ $\frac{6}{6} = 1$
2. 16 16 8
3. $16\frac{1}{2}$ $16\frac{1}{4}$ $12\frac{1}{2}$
4. $8\frac{2}{5}$ $5\frac{2}{3}$ $10\frac{3}{5}$
5. $16\frac{3}{8}$ $16\frac{1}{4}$ $18\frac{4}{5}$
6. $16\frac{1}{12}$ $17\frac{7}{8}$ $4\frac{17}{24}$
7. $1\frac{1}{24}$ $1\frac{11}{18}$ $1\frac{5}{36}$ $1\frac{41}{48}$
8. $54\frac{65}{72}$
9. $43\frac{5}{8}$

Subtract

1. $\frac{1}{9}$ $\frac{5}{12}$ $\frac{2}{24} = \frac{1}{12}$ $\frac{1}{4}$ $\frac{5}{10} = \frac{1}{2}$ $\frac{3}{12} = \frac{1}{4}$

2. $\frac{7}{18}$ $\frac{19}{30}$ $\frac{13}{48}$ $\frac{5}{24}$ $\frac{8}{21}$ $\frac{1}{18}$

3. $1\frac{1}{4}$ $6\frac{1}{4}$ $2\frac{1}{8}$ $1\frac{2}{5}$ $4\frac{2}{3}$

4. $7\frac{11}{15}$ $5\frac{3}{7}$ $5\frac{1}{5}$ $8\frac{1}{8}$ $4\frac{1}{2}$

5. $1\frac{11}{18}$ $\frac{26}{35}$

6. $2\frac{7}{24}$ $4\frac{29}{36}$

7. $1\frac{23}{36}$ $5\frac{5}{12}$

Find the Answers

1. $\frac{1}{4}$ 1 0

2. $2\frac{31}{90}$ $\frac{7}{8}$ $1\frac{1}{8}$

3. $\frac{2}{5}$ $\frac{1}{2}$ $\frac{14}{15}$

4. $\frac{7}{24}$

5. $6\frac{11}{36}$

VIII. Multiplication and Division of Fractions

1. 15 $13\frac{1}{2}$ 12

2. $2\frac{2}{5}$ $10\frac{1}{2}$ $6\frac{1}{4}$

3. $2\frac{1}{2}$ $2\frac{1}{2}$ $5\frac{1}{7}$

4. $\frac{1}{4}$ $\frac{3}{8}$ $\frac{3}{5}$

5. $2\frac{2}{3}$ $2\frac{1}{3}$ $2\frac{22}{49}$

6. $4\frac{1}{2}$ $1\frac{1}{4}$ 28

7. $160 \frac{5}{12}$

8. 175

9. 238

10. $10 \frac{8}{9}$

Divide

1.	$\frac{8}{5} = 1 \frac{3}{5}$	26	14
2.	$\frac{20}{21}$	$\frac{20}{21}$	1
3.	9	$\frac{1}{16}$	$\frac{2}{35}$
4.	$\frac{12}{7} = 1 \frac{5}{7}$	$\frac{7}{6} = 1 \frac{1}{6}$	$\frac{49}{30} = 1 \frac{19}{30}$
5.	$\frac{24}{7} = 3 \frac{3}{7}$	$\frac{4}{5}$	
6.	12	24	50
7.	$\frac{1}{24}$	$\frac{3}{20}$	$\frac{1}{24}$
8.	$\frac{2}{3}$	$\frac{3}{4}$	$\frac{7}{4} = 1 \frac{3}{4}$

IX. Decimals

Add

1. 4.453
2. 39.6627
3. 93.3941

Find the Answers

1. 4.027
2. .045
3. .02

Multiply

1.	.0112	.112	3.016
2.	32.016	219.905	769.304
3.	7.58940	20.4858	62.4890
4.	0.81	95,099.94	
5.	283,520.25	48,888.00	

X. Express as fractions in their lowest terms

1.	$\frac{1}{8}$	$\frac{3}{400}$	$\frac{5}{8}$
2.	$\frac{1}{16}$	$\frac{3}{8}$	$\frac{3}{80}$
3.	$\frac{191}{200}$	$\frac{7}{80}$	$\frac{13}{2000}$

Divide

1.	.03	.06	.0125
2.	.00375	3.88	.34
3.	.72	.805	.0035
4.	800	60	3200
5.	875	37.5	6.25
6.	7.5	15	85
7.	600	4.8	30
8.	14.7	6.8	2.5
9.	3152	1.62	28.12

Change to Decimals

.125	.05	.80	.75	.95	.48

Solve the following problems

1. 16
2. 40
3. 49
4. $2\frac{1}{4}$
5. 910 miles
6. $4\frac{1}{2}$ hrs.

XI. Percentage

Express as percent

1.	6.25%	8.75%	1.125%
2.	6.375%	4.875%	2.75%
3.	6.5%	5.1%	.9%
4.	325%	142%	504%
5.	405%	309%	600%

Express as Decimals

1.	.12	.625	.666
2.	.166	.1428	.375
3.	.0375	.125	.033
4.	1.06	.0033	.005
5.	1.15	0.001667	1.60

Express as Decimals and then as Percents

1.	.3, 30%	.6, 60%	.625, 62.5%
2.	.05, 5%	.06, 6%	.1667, 16.7%
3.	.667, 66.7%	.0625, 6.25%	.0833, 8.33%
4.	.111, 11.1%	.0938, 9.38%	.005, .5%
5.	.004, .4%	.0125, 1.25%	.0025, .25%

Express as Decimals and then as Fractions in their Lowest Form

1.	.6, $\frac{3}{5}$	.0625, $\frac{1}{16}$	.9, $\frac{9}{10}$	1.75, $1\frac{3}{4}$
2.	.125, $\frac{1}{8}$	.833, $\frac{833}{1000}$	.142857, $\frac{142857}{1,000,000}$	.05, $\frac{1}{20}$
3.	.0909, $\frac{0909}{10000}$	.008, $\frac{1}{125}$	.08, $\frac{2}{25}$	.6667, $\frac{2}{3}$

XII. Find the Missing Dimension

1. 46 ft.
2. 86 ft.
3. $32\frac{1}{3}$ ft.
4. $12\frac{1}{3}$ ft.
5. 16 ft.
6. 3 ft.
7. $7\frac{7}{16}$ ft.
8. 23 ft.
9. 54 ft.
10. 252 ft.

XIII. Find the AREA of the following Squares

1.	81 sq. in.	196 sq. in.	64 sq. yd.
2.	676 sq. in.	400 sq. ft.	21.16 sq. yd.
3.	$6.25		
4.	9 sq. yds.		
5.	168 sq. yds.		

Find the Missing Dimension

1. 120 sq. ft.
2. 32 sq. ft.
3. 1936 yds.
4. 1440 tiles
5. 4 yds.
6. $6.72
7. 45 ft.

XIV. The Circle

Find the Missing Dimension

1.	3 in.	10 in.
2.	87.96 in.	$3\frac{1}{2}$ ft.
3.	3.5 in.	109.96 in.
4.	659.73 ft.	
5.	1.57 ft.	

Find the Area of the following when

1.	38.48 sq. in.	153.94 sq. in.
2.	17.10 sq. ft.	7.07 sq. yd.
3.	346.36 sq. ft.	6.16 sq. yd.
4.	962.12 sq. in.	
5.	A. = 28.27 sq. ft.	c. = 18.85 ft.

XV. Volume

Find the Volume of the following Rectangular Solids

1. 400 cu. in.
2. 150 cu. in.
3. 49.0 cu. ft.
4. 512 cu. in.
5. 15.625 cu. in.
6. 216 cu. ft.
7. 189 cu. ft.
8. $3\frac{3}{8}$ cu. ft.
9. 27
10. 8

Find the Volume of the following Cylinders

1. 2.28 gal.
2. 548.22 gal.
3. 1823.98 gal.
4. 767.58 gal.
5. 115.11 gal.
6. 8,812.19 gal.
7. 247.84 gal.
8. 117.81 cu. ft. or 881.2 gal.
9. 3436.12 cu. ft.; 25,702.215 gal.
10. a) 2500 cu. ft.
    b) 112,200 gal.
    c) 12,500 cu. ft.
    d) 6,600.1 gal.

Problem Solving Technique

1. 180 mi.
2. 39 gugs
3. 120 g. Cu
4. 10 hrs.
5. 16.67 gpm

Carry out the following conversions

1.	54 in.	9 in.
2.	20 ft.	220 in.
3.	4.5 ft.	2.5 yds.
4.	0.3 cm.	5,200 cm.
5.	1.22 km.	1,000 ml.
6.	0.02 kg.	500 mg.
7.	762 cm.	2.09 lbs.
8.	4.72 l.	2.26 m.
9.	56,700 mg.	20.5 kg.

10. $\frac{\text{12.72 qts.}}{\text{12 qts.}} = \frac{\text{1.06 qts.}}{\text{1 qt.}}$

11. 1.4%

12. 0.135 mgd; 900 gal. per person

XVI. Calculations for Water Treatment Plant Operators

1. 8.34 lbs.
2. 62.43 lbs.
3. .1337 cu. ft.
4. .720 mgd.
5. 7.48 gal.
6. a. gallons per day
   b. grains per day
   c. million gallons
   d. milligrams
   e. parts per million
   f. million gallons per day
   g. gallons per minute
   h. liter
   i. meter
7. 1 mg./l.; 8.34 lbs./M.G.; 0.06 gpg
8. a. 6 ppm
   b. 68.5 ppm
   c. .24 ppm
   d. 10 ppm
   e. 4 mg./l.
   f. 83.4 lbs./M.G.
   g. 1.46 gpg
9. B
10. Yes
11. 85.6 ppm
12. 250.2 lbs.
13. 8.34 lbs.
14. 10 ppm
15. 1 gpg; 17.12 ppm; 142.8 lbs./M.G.
16. 500 mg./l.; 50 cg./l.; 5 dg./l.; .5 g./l.
17. 83.4 lbs.
18. 3.5 lbs.
19. 1.2 ppm
20.

ppm	gpg
14.96	0.87
7.19	0.42
0.95	0.056
0.72	0.042

21. 0.007 gal./min.
22. .14 gal./min.
23. 8,181.25 gal.
24. .4 in./min.

25. a. 4.01
    b. 5610 gpm
    c. 2.01
    d. 3786.75 gpm

26. a. 2.22
    b. 2.076
    c. 0.56
    d. 0.59

27. a. 356.535 lbs.
    b. 428.58 lbs.
    c. 535.5 lbs.
    d. 428.34 lbs.
    e. 475.94 lbs.
    f. 476.2 lbs.
    g. 630 lbs.
    h. 713.9 lbs.

28. 535.5 lbs.

29. 257.04 lbs.

30. 3.36 hrs., 201.95 min.

31. 420.75 min.

32. a. 3.23
    b. 0.054
    c. 11.59
    d. 0.28

33. a. 2.8
    b. 3.6
    c. 0.14
    d. 95.92
    e. 0.52
    f. 8.95

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page refers to the topics discussed in this module which are found in that book.

1. Course in Applied Mathematics for Water and Wastewater Personnel, Sponsored by Michigan Section AWWA, Michigan Water Pollution Control Association and Michigan Department of Public Health.
2. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY, pp. 241-256.
3. Manual of Water Utility Operations, Texas Water Utilities Association Austin, TX, pp. 610-630.
4. Mathematics Made Simple, by A. Sperling and M. Stuart, Made Simple Books, Doubleday and Company, Inc., Garden City, NY.
5. Operation of Wastewater Treatment Plants, California Water Pollution Control Association, Environmental Protection Agency, Sacramento, CA, Chapter 15.

POST - TEST (4 pts. each)

1. A rectangular box is 20 inches long. Its width is $\frac{1}{5}$ as much. How wide is it?
2. If you traveled $\frac{7}{8}$ of the distance to work by car and walked the rest of the way, how far is it to work if you walked 440 yards?
3. If a bin 75% full holds 10 bushels of grain, what is its capacity?
4. Last week Mr. Smith drove his car 257.3 miles and used 14 gallons of gasoline. How many miles per gallon did the car average?
5. In Jone's Lake, last spring 450 fish were caught. If 50 of these were bass, what percent was not bass?
6. How much lumber is contained in a table 8 feet 2 inches by 4 feet 6 inches?
7. What is the circumference of a pipe opening with a radius of .5 meters? What is its area?
8. What is the volume of a tool box 50 cm. long, 22 cm. wide and 28 cm. high?
9. A tank $3\frac{1}{2}$ yards high with a diameter of $1\frac{3}{4}$ yards has what capacity (in gallons)?
10. What is the pumping rate in gallons per minute of a tank filled in seven hours if its capacity is four thousand five hundred gallons?
11. How many gallons of water are there if the water weighs 24.12 pounds?
12. How many pounds are there in a cubic foot of water?
13. 750 gpm is equal to how many mgd?
14. What do these abbreviations mean:
    a. gpg b. ppm c. gpm d. M.G.
15. How many ppm of Iron is there in 1.5 M.G. of water treated with 20 pounds of Iron?
16. A water treatment plant treats 2,000,000 gallons of water a day. Calculate the gpg of lime in this water if 200 lbs. of lime was added to it.
17. A filter 15 ft. by 10 ft. was rinsed with 7 gallons per minute of water. What is the inches of rise per minute?
18. How many pounds of chlorine (70%) is needed to treat 4,500,000 gallons of water to obtain a 1.0 gpg dosage?
19. What is the detention time of a basin 100 feet long, 50 feet wide and 30 feet deep which is used to treat 7,000 gallons per minute?
20. If 250 lbs. of chemical is used to treat 9 M.G., what is the dosage of chemical used in mg./l.?

POST-TEST ANSWERS

1. 4 in.
2. 3520 yards
3. 13.33 bushels
4. 18.38 miles/gal.
5. 89%
6. 5292 sq. in. or 36.75 sq. ft.
7. 3.14 meters, 0.79 sq. meters
8. 30,800 cu. cm.
9. 1700.2 gal.
10. 10.7 gal./min.
11. 2.89 gals.
12. 62.38 lbs./cu. ft.
13. 1.08 mgd
14. a) gpg = grains per gallon b) ppm = parts per million
    c) gpm = gallons per minute d) M.G. = million gallons
15. 1.6 ppm
16. 0.7 gpg
17. 0.075 inches of rise per min.
18. 918.0 lbs.
19. 160.29 min.
20. 3.33 mg./l.

MODULE 2

SELF-INSTRUCTIONAL

Paul Hummel - NMSU

BASIC CHEMISTRY

PREREQUISITES: None

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. Classify these substances as either a liquid, solid, or gas. (12 pts.)
   a. Chlorine at room temperature (Cl_2)
   b. Salt (NaCl)
   c. Hydrogen Sulfide (H_2S)
   d. Water (H_2O)
   e. Quick lime (CaO)
   f. Air
2. Classify these substances as either an element, a compound or a mixture. (12 pts.)
   a. Hydrogen (H_2)
   b. Sand
   c. Sodium Chloride (NaCl)
   d. Sodium (Na)
   e. Air
   f. Water (H_2O)
3. Name three physical characteristics of matter. (6 pts.)
   a.
   b.
   c.
4. Classify the following reactions as a chemical or a physical change. (6 pts.)
   a. Melting of snow
   b. Salt dissolved in water
   c. Rusting of iron
5. If the atomic weight of an element is 40 and the atomic number is 18, how many neutrons are in the nucleus? How many protons? (8 pts.)
   a.
   b.
6. Write the symbols for the following elements. (16 pts.)
   a. Calcium
   b. Sodium
   c. Oxygen
   d. Zinc
   e. Chlorine
   f. Sulfur
   g. Nitrogen
   h. Iron
7. Write the symbols for the following compounds. (12 pts.)
   a. Sulfuric acid
   b. Soda ash (sodium carbonate)
   c. Lye (sodium hydroxide)
   d. Filter alum (aluminum sulfate)
   e. Limestone (calcium carbonate)
   f. Salt (sodium chloride)

8. Hardness in water is caused by what four elements? (8 pts.)
   a.
   b.
   c.
   d.

9. Classify these substances as an acid, base or salt. (10 pts.)
   a. Hydrochloric (HCl)
   b. Potassium hydroxide (KOH)
   c. Potassium chloride (KCl)
   d. Ammonium hydroxide (NH_4OH)
   e. Cupric sulfate ($CuSO_4$)

10. Given the following pH's, classify them as acidic, basic or neutral. (10 pts.)
    a. 7
    b. 2
    c. 10
    d. 8.5
    e. 4.8

ANSWERS

1. a. gas
    b. solid
    c. gas
    d. liquid
    e. solid
    f. gas

2. a. element
    b. mixture
    c. compound
    d. element
    e. mixture
    f. compound

3. Any three: odor, density, physical state, solubility, freezing, boiling point.

4. a. physical change
    b. chemical
    c. chemical

5. a. 22
    b. 18

6. a. Ca
    b. Na
    c. O
    d. Zn
    e. Cl
    f. S
    g. N
    h. Fe

7. a. H_2SO_4
    b. Na_2CO_3
    c. Na OH
    d. $Al_2\ (SO_4)_2$
    e. Ca CO_3
    f. Na Cl

8. a. Ca
    b. Mg
    c. Na
    d. Mn

9. a. acid
    b. base
    c. salt
    d. base
    e. salt

10. a. neutral
    b. acid
    c. base
    d. base
    e. acid

INTRODUCTION

You will be dealing with, or already are, chemical processes in your job as a Water Treatment Plant Operator. This module is designed to give you background to the processes taking place in your role as a chemist. Some of your duties will include softening water and removing unwanted tastes and odors. After completing this module, you will have a better understanding of what you are doing.

Don't let the word Chemistry scare you. True, it is not an easy subject, but if you read the following module carefully you will see that it is not an impossible subject to master.

PERFORMANCE OBJECTIVE

When this module is completed, you will be able to show that you have mastered the following concepts:

1. Chemical Shorthand
2. Solutions and Suspensions
3. Coagulation
4. Water Softening
5. pH

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

MATTER

Matter is anything that occupies space and has weight. It can be neither destroyed nor created by ordinary chemical means. When one burns a log, for example, one might think that as the wooden log burns it is destroyed. This is not the case; if all the gases and ashes formed during burning were collected and weighted, the total weight would be equal to that of the log plus the oxygen required to burn it.

Matter may take one of three shapes. It can be a solid, a liquid or a gas. Solids have a definite shape and volume. Liquids have a definite shape or volume. A gases shape and volume is dependant on the container it is in.

At ordinary room temperature and under normal pressure, the form matter takes is called its physical state. If the temperature or pressure is changed, it is possible to change the physical state. For example, water is a liquid at normal room temperature and normal pressure. If the temperature is lowered to below 32 degrees Fahrenheit and the pressure is kept constant, the liquid water is changed to a solid (ice). If the temperature is raised above 212 degrees Fahrenheit and the pressure is kept constant, water will change to a gas (steam).

Matter can be divided into three catagories. These are: 1. elements; 2. compounds; and, 3. mixtures. An element is a substance that cannot be broken down by ordinary chemical means into a simpler substance. There are 103 known chemical elements: some of which are hydrogen (H_2); oxygen (O_2); copper (Cu); and iron (Fe).

A compound is a substance which can be broken down into elements by ordinary chemical means. Water (H_2O) is an example of a chemical compound. It is composed of the elements of hydrogen (H_2) and oxygen (O_2).

A mixture is a substance composed of various compounds, elements or some of both. Mixtures, unlike compounds, do not have their components united by chemical means. Therefore, parts of mixtures can be separated by physical means. Sand and iron filings is a mixture. The iron in this mixture can be removed by means of a magnet. Other mixtures are sand and air.

Matter has certain characteristics or properties which helps us to identify what it is made of. These properties can be catagorized into two kinds: 1. physical properties; and 2. chemical properties. Odor, taste, density, physical state, solubility, freezing and boiling point make up the physical properties of matter. Chemical properties include its chemical activity, stability, and its reaction to other chemicals, light and heat.

As well as having chemical and physical properties, matter can also change physically or chemically. If the chemical properties of a substance remains constant but the physical properties change, one says that this matter has undergone a physical change. The chemical properties are the same but the physical properties have changed. The burning of a log is considered a chemical change. The log changes chemically when it is combined with oxygen to form new substances, e.g., water vapor, carbon dioxide and mineral ash.

SELF-TEST

1. Anything that occupies space and has weight is called __________.	matter
2. A solid is defined as having a definite __________ and __________.	shape, volume
3. An __________ cannot be broken down into a simpler substance by ordinary chemical means.	element
4. Air is considered a __________ because it is composed of oxygen, nitrogen and various other gases.	mixture
5. Odors, tastes and solubility are considered to be __________properties.	physical
6. A burning candle is undergoing a __________change.	chemical

ATOMIC STRUCTURE

An elementary knowledge of atoms is necessary for an understanding of why certain procedures are used in the water treatment plants. Concepts such as pH and coagulation are based on a knowledge of atoms and their properties. The following section will present to you a working knowledge of these principles.

An atom is composed of a nucleus and particles orbiting this nucleus called electrons. The nucleus found in the center of the atom can be made up of two types of particles called protons and neutrons. One can think of an atom as a miniature solar system. The nucleus being the sun and the electrons as the planets.

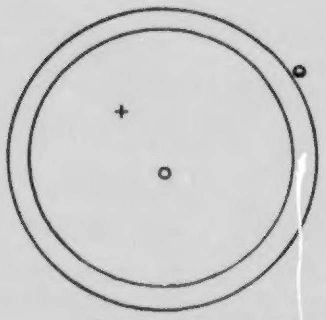
Electrons are particles having a negative electrical charge (-) and is considered to be weightless. Protons have a positive charge (+) and weigh 1,837 times as much as an electron. There are always the same number of electrons orbiting the nucleus as there are protons in it. The third particle in the atom is the neutron. It weighs as much as a proton but has no charge on it.

The simplest atom is the hydrogen atom. It has a single proton and one electron orbiting it. Helium is a more complex atom because it has two electrons orbiting two protons. Lithium has three electrons and three protons. Each element or atom has a certain number of protons in the nucleus with the same number of electrons. The number of protons in the nucleus is characteristic of an atom and can help us identify that atom. This number of protons is called the atomic number.

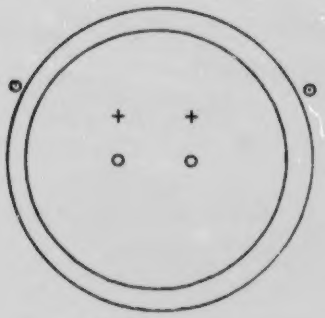
One can say that in general there are the same number of neutrons in the nucleus as there are protons. There are some atoms though that have different numbers of each particle but for the most part both are equal.

Since the weight of the neutron is equal to that of the proton, the weight of an atom will equal the sum of the number of protons and neutrons. This sum is called the atomic weight. For example, the atomic weight of the neon atom is 20 and its atomic number is 10. This means that there are 10 neutrons in the nucleus and 10 protons.

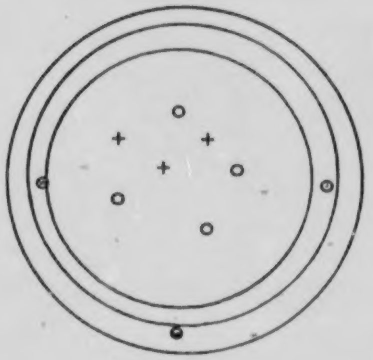
FIGURE 1



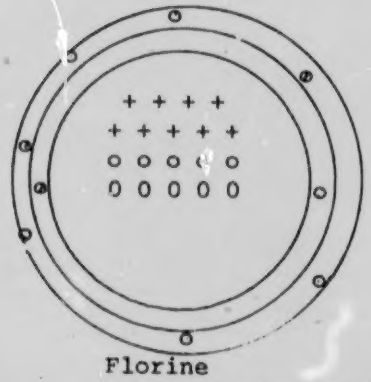
The Hydrogen Atom
Atomic Number -1
Atomic Weight -2



Helium
Atomic number - 2
Atomic Weight - 4



Lithium
Atomic Number - 3
Atomic Weight - 7



Florine
Atomic Number - 9
Atomic Weight - 19

o : Neutron ⊙ : Electron + : Proton

SELF-TEST

1. The two particles types found in the nucleus of an atom are __________ and __________.	neutron proton
2. Electrons have a __________ charge.	negative -
3. Protons have a __________ charge.	positive +
4. There are the same number of electrons in the atom as there are __________.	protons
5. Is there always the same number of protons as there are neutrons in the nucleus?	No
6. The atomic number tells the number of __________ or __________.	protons electrons
7. The atomic weight tells the number of __________ plus __________.	protons neutrons

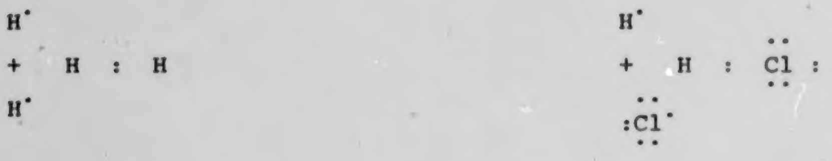
MOLECULES

Atoms are the basic units of elements. Atoms may also unite to form tightly bound groups called molecules. These groups are the smallest part of a substance that has the properties of a larger mass of the substance. The weight of these molecules (molecular weight) is equal to the sum of the weights of the atoms (atomic weight) of the molecules. If one has a tank of oxygen for example, one unit of oxygen in this large mass of oxygen is considered to be a molecule. Therefore, many molecules are found in the oxygen tank.

The bonds or glue which hold a molecule together can be one of two types. One type of bond is formed when two atoms share their electrons. An example of this type of bond is seen in the hydrogen molecule. While hydrogen has a single electron in its orbit, it can accommodate two. This makes it possible for two atoms of hydrogen to share electrons. The molecule formed in this way is very stable. Gases are an example of molecules held together by this type of bond or glue.

Another type of bond which holds molecules together is one in which the atoms exchange electrons. Figure 2 shows an example of this type of bond. Here, hydrogen and chlorine exchange electrons. Hydrogens with one electron in its outer orbit gives up its electron to chlorine which has seven electrons in its outer orbit. (Chlorine needs one electron to complete its orbit). Since chlorine takes the hydrogens electron for its own, the hydrogen nucleus becomes attached to the chlorine atom.

FIGURE 2



$H^{\cdot}$

$+ \quad H : H$

$H^{\cdot}$

$H^{\cdot}$

$+ \quad H : \overset{..}{\underset{..}{Cl}} :$

$:\overset{..}{\underset{..}{Cl}}^{\cdot}$

Shared electron bond

Exchanged electron bond

. = electron

H = Hydrogen

Cl = Chlorine

SELF-TEST

1. The smallest part of a substance that has the properties of a larger mass of the substance is called a __________?	molecule
2. Gases are examples of molecules held together by __________.	shared electron bonds
3. When one atom takes the electrons of another atom for its own and in the process binds the other atom to it, the bond formed is called __________?	exchanged electron bond
4. The molecular weight is found by adding together the __________ __________ of the atoms of the molecule.	atomic weight

CHEMICAL SHORTHAND

Throughout this module and in many of the following ones you will encounter letters representing chemical elements and compounds. For example, you will see chlorine abbreviated as Cl or oxygen as O_2. These abbreviations or symbols are a form of chemical shorthand since it is much easier to use one or two letters than writing out a full name. These symbols can be taken from the English or Latin name of the element they represent. Some, such as oxygen (O_2), hydrogen (H_2), and chlorine (Cl) have symbols which come from the first letter or letters of their English name. Others, such as iron (Fe), copper (Cu), and sodium (Na) take their symbols from the Latin version of their names. Iron, for example, is symbolized by Fe from the Latin word ferrum (which means iron). Copper or Cu comes from cuprum and sodium's symbol, Na, comes from natrium. The use of symbols which have their origins from the Latin word for the elements has come about since there are 105 elements and only 26 letters in our alphabet. This shortage of letters has also resulted in most elements having two letter symbols, with only the first one capitalized. A good rule to remember is that generally the letter symbols are the first two letters of the name of the element. In some cases, where the first two letters are used to represent another element, the first and third letters are used. An example of this is the symbol for cadmium (Cd). Here, the first and third letters are used since Ca is already used to represent another element - calcium. The most common symbols appear in Table 1 and should be learned.

TABLE 1

Common Elements and Their Symbols

Element	Symbol	Element	Symbol
Aluminum	Al	Carbon	C
Calcium	Ca	Chlorine	Cl
Copper	Cu(cuprum)	Flourine	F
Iron	Fe(ferrum)	Helium	He
Magnesium	Mg	Hydrogen	H
Manganese	Mn	Iodine	I
Potassium	K(kalium)	Nitrogen	N
Silver	Ag(argentum)	Oxygen	O
Sodium	Na(natrium)	Phosphorus	P
Zinc	Zn	Sulfur	S

Just as it is easier to write symbols for the elements, it is easier to use what are called formulas for compounds (groups of various elements). For example, the formula for table salt in sodium chloride is NaCl. This formula, NaCl, shows that this compound is made up of one sodium (Na) atom and one chlorine (Cl) atom. H_20 is another way of representing the compound we call water. The formula H_20 shows that for every oxygen (O) atom there are two hydrogen (H) atoms. The small number following a symbol or group of symbols applies only to that symbol or groups of symbols. For example, the 2 following the parenthesis in the formula for calcium hydroxide, $Ca\ (OH)_2$, shows that there are two sets of (OH) molecules for one atom of calcium (Ca). If the number is outside of the parenthesis as in $Ca\ (OH)_2$, calcium hydroxide, the atoms inside the parenthesis are considered to be a unit. These units are called radicles. Formulas for some common chemicals are given in Table 2.

TABLE 2

Chemical	Symbol	Common Name
Ammonia (gas)	NH_3	Ammonia gas
Calcium oxide	CaO	Quick lime
Ferric chloride	$FeCl_3 \cdot 6H_20$	
Hydrochloric acid	HCl	Muriatic acid
Sulfuric acid	H_2SO_4	
Sodium chloride	NaCl	Salt
Sodium fluoride	NaF	
Sodium silicofluoride	Na_2SiF_6	
Hydrofluosilicic acid	H_2SiF_6	

Some Common Chemicals, Their Formulas and Common Names

Radicles can be thought of as groups of atoms glued tightly together. The energy needed to dissolve this glue is so great that in most cases the atoms in the radicle cannot be separated. As was explained in the case of calcium hydroxide ($Ca(OH)_2$), OH is a radicle. This radicle is also found in the compound sodium hydroxide ($Na\underline{OH}$), magnesium hydroxide ($Mg(\underline{OH})_2$) and ammonium hydroxide ($NH_4\underline{OH}$). As you may have guessed already the name of this radicle (OH) is hydroxide. Other radicles are SO_4 (sulfate) found in copper sulfate ($CuSO_4$), CO_3 (carbonate) found in magnesium carbonate ($MgCO_3$) and NO_3 (nitrate) found in calcium nitrate ($Ca(NO_3)_2$). Table 3 shows other radicles, their names and a representative compound each are found.

TABLE 3

Radicle	Symbol	Example
Ammonium	NH_4	Ammonium hydroxide, NH_4OH (ammonia)
Carbonate	CO_3	Calcium carbonate, $CaCO_3$ (limestone)
Bicarbonate	HCO_3	Sodium carbonate, Na_2CO_3 (soda ash); Calcium bicarbonate, $Ca(HCO_3)_2$ Sodium bicarbonate, $NaHCO_3$ (soda)
Hydroxide	OH	Calcium hydroxide, $Ca(OH)_2$ (hydrated lime) Sodium hydroxide, NaOH (lye)
Sulfate	SO_4	Cupric sulfate, $CuSO_4 \cdot 5H_2O$ (copper sulfate) Aluminum sulafte, $Al_2(SO_4)_3 \cdot 18H_2O$ (filter alum)

Common Radicles, Their Symbols and a Representative Example of Each

SELF-TEST

1. S is the symbol for __________.	sulfur
2. H_2O is the __________ for water.	formula
3. The formula $Al(OH)_3$ shows that for every atom of Al there are __________ OH radicals.	three

WATER

Since you will be dealing with water or already have, it is important that you know something about this substance. Water is a compound composed of one atom of oxygen (O) to two of hydrogen (H). It will freeze at 32° Fahrenheit (0°C) and boil at 212° Fahrenheit (100°C). Water is peculiar in that it becomes heavier as it becomes colder. So, that at 39.2° Fahrenheit (4°C), it is heavier than at higher temperatures. But as water becomes colder than 39.2°F (4°C), it again starts to become lighter. Therefore, water is heaviest at 39.2°F (4°C). This phenomonon is important since ice will float on water. Thus, lakes and other bodies of water will not freeze completely to the bottom. Water also expands as it turns into ice. This is why water pipes burst during extremely cold weather.

Water is also called the universal solvent because of one unique property. It will dissolve, to a certain extent, most natural substances whether they be a gas or a solid. Since water will dissolve almost anything, pure water (a colorless, odorless, tasteless liquid) is not found in nature. It is contaminated with something and these contaminates give it any odor, taste or color.

The fact that water will dissolve anything means that even rain water is not completely free of contaminants. As rain falls to earth, it picks up carbon dioxide (CO_2) making it slightly acid. When it reaches the earth, water will dissolve minerals from rocks. The most soluble minerals being dissolved first.

What water picks up as a contaminant on earth depends on what type of earth or geological formation it passes over. For example, water passing over granite formations will pick up few minerals. This is because the minerals in granite are relatively insoluble. If water passes over limestone, the mineral content of the water is higher. This is due to the fact that limestone or calcium carbonate ($CaCO_3$) is more soluble in water, especially waters containing dissolved carbon dioxide. Gypsum formations or calcium sulfate ($CaSO_4$) yield water with a high content of minerals. As might be expected, calcium sulfate is highly soluble in water. These are only three examples of geological formations found on earth. One may find these only, or combinations of these or even other types of earth. Thus an infinite number of water types may result because of the complex nature of earth geology.

The reaction of minerals in water is important for the water treatment plant operator to know because of conditions called water hardness, alkalinity and acidity. Before we explain why it is important to know about these phenomona, let us look at what happens when water and certain minerals come in contact with each other.

Minerals, as they enter the water, come apart. In other words, they cease to exist in their original form. Gypsum ($CaSO_4$ or calcium sulfate) will break apart into calcium (Ca^{++}) and sulfate (SO_4--) ions. Ions are particles which carry electrical charge. The breakdown of calcium sulfate ($CaSO_4$) produces positive ions of calcium (Ca^{++}) with two charges and negative ions of sulfate (SO_4--) with two negative charges. The plus or minus signs above the symbol for an element indicate that it is an ion as well as what kind and how powerful a charge it has. One must remember that when dealing with ions, the number of positive charges on an ion or group of ions must equal the number of negative charges on another ion or group of ions. Salt (NaCl or sodium chloride) is another example of a substance that comes apart in water. In this case, sodium chloride (NaCl) dissolves into sodium ions (Na^+) and chloride ions (Cl-). Dolomite or calcium magnesium carbonate ($CaMg(CO_3)_2$) dissolves into calcium ions (Ca^{++}), magnesium ions (Mg^{++}) and two carbonate ions (CO_3--).

In natural waters, two types of ions are present. These are positive and netagive ions. Among the positive ions are calcium (Ca^{++}) from limestone ($CaCO_3$), dolomite ($CaMg(CO_3)_2$) and gypsum ($CaSO_4$), magnesium (Mg^{++}) from dolomite and other magnesium bearing formations and sodium (Na^+) from salt found associated with earth formations. The four primary negative ions found in water are bicarbonate ions (HCO_3--), carbonate (CO_3--), sulfate (SO_4--) and chloride (Cl-). These ions come from the geological formations we talked about previously. In some cases, they may come from gas molecules dissolving in the water.

HARDNESS

One of the things dissolved minerals in the form of ions cause is a condition **called** hardness. Water which is hard will not react with soap to produce suds and will also form undesirable insoluble scum (found in bathtub rings and sticky hair). Hard water is caused by ions of calcium (Ca^{++}) and magnesium (Mg^{++}) in combination with one of four negative ions. These negative ions are carbonate ions (CO_3--), bicarbonate ions (HCO_3--), sulfate ions (CO_4--) and chloride ions (Cl-). Hard water can be divided into two types depending on which type of negative ions are present.

Temporary or carbonate hardness is caused by calcium (Ca^{++}) and magnesium (Mg^{++}) present with carbonate (CO_3--) or bicarbonate (HCO_3--) ions. This type of hardness can be removed by boiling or by adding lime. Non-carbonate or permanent hardness is due to the presence of negative ions that can be chlorides (Cl-) or sulfates (SO_4--). Of course, the positive ions of calcium (Ca^{++}) and magnesium (Mg^{++}) are also present. Permanent hardness is removed by chemical means.

It is important to know which type of hardness is present in the waters you are treating so that you use the best method possible to remove the calcium (Ca^{++}) and/or magnesium (Mg^{++}). When these are removed, the water is said to be soft. This softening process can be accomplished either by chemical precipitation or by ion exchange. In chemical precipitation, calcium (Ca^{++}) and magnesium (Mg^{++}) are changed into insoluble substances and are physically removed. In ion exchange, these positive ions are exchanged with sodium (Na^{++}). Sodium (Na^{++}) in moderate amounts is not objectable since it does not prevent sudsing of soaps. More will be said about softening in another module.

ALKALINITY AND ACIDITY

Alkalinity of natural waters is due to the presence of three types of ions - bicarbonates (HCO_3--), carbonates (CO_3--) and hydroxides (OH). These types of substances result from the reaction of calcium (Ca) and magnesium (Mg) atoms which dissolve in water to form ions. These two elements occur naturally in stream and river beds which have a rock base.

Alkalinity information is used in the treatment of water. In coagulation, the alkalinity of the water acts as a stabilizer or buffer to hold the pH constant so that coagulants can be effective. Alkalinity is important in the softening of water in determining the amount of lime and soda-ash required to treat the water.

Natural waters become acidic because of the presence of mineral acids such as HCl, H_2SO_4, H_3PO_4 and HNO_3. These can enter the water as a form of pollution from mine wastes and ore dumps.

Natural waters can also become acidic from the formation of carbonic acid. This acid comes from CO_2 (carbon dioxide) in the atmosphere which dissolves in the water to form carbonic acid.

OTHER IMPURITIES IN THE WATER

Iron (Fe) in water comes from dissolved impurities from the earth's crust or may come from corrosion of iron mains, pumps and pump casings. It will stain clothes during washing and plumbing fixtures when present in quanitites greater than 3 mg./l.

Manganese (Mn) will produce results similar to iron (Fe) when present in the water. It is troublesome at lower concentrations though (0.05mg./l.)

Chlorides (Cl-) not only participate in causing hardness problems but also give the water a salty taste. Present in quantities greater than 250 mg./l., this ion can be tasted. It is not easy to remove.

Nitrogen salts when found in more than extremely small quantities, indicate a contamination by human wastes. These substances are reported in terms of the nitrogen (N) present in ammonia (NH_4^+) and nitrates (NO_3-) - nitrites (NO_2-).

SELF-TEST

1.	Taste, odor and color is caused by __________ in the water.	impurities
2.	Ice floats because it becomes __________dense when it expands.	less
3.	Water is called the __________.	universal solvent
4.	Temporary or carbonate hardness in water is caused by __________ and __________ atoms.	calcium magnesium
5.	Temporary hardness can be removed by __________ or by adding __________.	boiling, lime
6.	Calcium sulfate makes water __________ hard.	permanently
7.	This type of hardness must be removed by __________.	chemicals

ACIDS, BASES AND SALTS

In the last section, we discussed acidity, alkalinity and one kind of salt (nitrogen salts). In order to understand what these terms mean as well as a concept called pH, we first must understand what an acid, base or salt is.

Acids are chemical substances whose water solutions contain hydrogen (H^+) ions. In other words, an acid is a substance that when dissolved in water, will give positive hydrogen (H^+) ions and some type of negative ions. Hydrochloric acid (HCl), carbonic acid (H_2CO_3), nitric acid (HNO_3) and sulfuric acid (H_2SO_4) are examples of acids. You will notice that the formulas for each of these substances contain at least one hydrogen atom (H). In water, these substances yield the following ions:

Hydrochloric acid (HCl) $HCl = H^+ + Cl^-$

Carbonic acid (H_2CO_3) $H_2CO_3 = H^+ + HCO_3^-$

Nitric acid (HNO_3) $HNO_3 = H^+ + NO_3^-$

Sulfuric acid (H_2SO_4) $H_2SO_4 = 2H^+ + SO_4^{--}$

Some of these acids such as hydrochloric (HCl), nitric acid (HNO_3) and sulfuric acid (H_2SO_4) will yield a large number of hydrogen ions (H^+). These are considered to be strong acids. Other acids such as carbonic acid (H_2CO_3), boric acid (H_3BO_4) and hydrogen sulfide (H_2S) produce a smaller number of hydrogen ions (H^+). These are thought of as weak acids.

A base is a chemical substance whose water solutions contain hydroxide ions (OH^-). In other words, hydroxide ions (OH^-) are produced when the substance dissolves in water. Examples of bases are sodium hydroxide (NaOH), calcium hydroxide ($Ca(OH)_2$) and iron hydroxide ($Fe(OH)_3$). The dissociation of these substances in water are as follows:

Sodium hydroxide (NaOH) $NaOH = Na^+ + OH^-$

Calcium hydroxide ($Ca(OH)_2$) $Ca(OH)_2 = Ca^{++} + 2OH^-$

Iron hydroxide ($Fe(OH)_3$) $Fe(OH)_3 = Fe^{+++} + 3OH^-$

As in acids there are strong bases as well as weak bases. This division is based on how many hydroxide ions (OH-) a substance will yield. Sodium hydroxide (NaOH), a strong base, will yield a high concentration of hydroxide ions (OH-). Calcium hydroxide ($Ca(OH)_2$) and iron hydroxide ($Fe(OH)_3$), weak bases, yield a low concentration of hydroxide ions (OH-).

Salts result from the reaction of a base and an acid. For example when hydrochloric acid (HCl) and sodium hydroxide (NaOH) are mixed together a salt (NaCl) and water (H_2O) is produced.

$$HCl + NaOH = NaCl + H_2O.$$

When salts are dissolved in water neither hydrogen ions (H+) or hydroxide ions (OH-) are produced in most cases. Sodium chloride (NaCl) for example when dissolved in water produces sodium (Na+) and chloride ions (Cl-).

$$NaCl = Na^+ + Cl^-$$

In cases such as these when neither hydrogen (H+) or hydroxide (OH-) ions are produced, the salt is said to be neutral.

Salts produced from a strong acid and a weak base, such as aluminum sulfate ($Al_2(SO_4)_3$) are considered to be an acidic salt. This is because when this salt is dissolved in water hydrogen ions are produced. The reaction is more complex than what we can deal with at this time but essentially what happens is that this salt when put in water reacts with the water to produce hydrogen ions (H+) from the water.

A weak acid and a strong base will produce a basic salt. An example of a basic salt is sodium carbonate (Na_2CO_2). When this salt is put in water it will produce hydroxide ions (OH-) among others.

pH

As mentioned in the previous section, when acids and bases dissolve in water they produce ions. These released ions will vary in the number produced depending on the kind of acid or base dissolved.

In 1909, a scale was invented to measure the amount of ions produced. The letter p was chosen to represent the power of ionization. Therefore, pH came to be used as the term to express the power of ionization of the hydrogen ion. In other words, it measures the concentration or amount of hydrogen ions present.

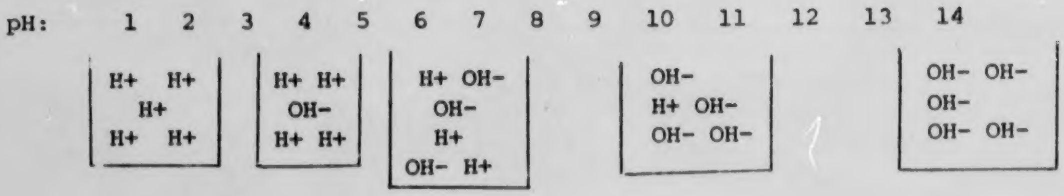
The pH scale runs from 0 to 14. 0 represents a substance which has produced the most hydrogen atoms. 14 represents a substance which has produced the least amount of hydrogen ions.

If one talks about the concentration of OH (pOH) the scale reverses. 0 represents the substance with the least amount of OH ions and 14 with the most.

Earlier we mentioned that an acid has hydrogen ions (H^+) and bases have hydroxide ions (OH^-). We can see, therefore, that 0 on the pH scale shows a very strong acid (the one that produces the most H^+ ions and the least amount of OH^- ions.) 14 on the other hand, represents a strong base because this substance produces the most hydroxide (OH^-) and the least amount of H^+ ions.

It is evident that the water molecule is made up of H^+ and OH^- groups (HOH is another way of writing H_2O). This substance is neutral in that in water there is very little ionization. In the ionization that does take place (one H_2O molecule out of 10 million molecules ionizes), the amount of H^+ ions equals the amount of OH^- ions. This substance, water, is neutral and assigned the number midway in the scale, 7.

Therefore, if a substance has a pH value from 0 to 6.9, it is said to be acidic. The closer this substance is to 0, the stronger it is. Sulfuric acid (H_2SO_4) is more powerful than acetic acid ($HC_2H_3O_2$). If a solution has a pH value from 7.1 to 14, it is said to be basic or alkaline. Again, the closer the substance is in pH value to 14, the stronger it is. 7.0 is neutral.



pH Scale

TABLE 2

pH		Example
14	Highly Basic	4% Caustic Soda
13		
12		Milk of Lime
11		
10		Milk of Magnesia
9		Borax
8		Egg White
7	Neutral	Pure Water
6		Milk
5		American Cheese
4		
3		Orange Cheese
2		
1	Highly Acidic	Lemon Juice
0		5% Sulfuric Acid

pH Vlaues of Some Common Substances

(Taken from the "Manual of Water Utility Operations", C. H. Billings, ed., p. 168.)

pH can be measured electrically with a pH meter or by substances called indicators. These are substances that change colors at various pH levels. One example of an indicator is litmus paper. Blue litmus paper when put in a base stays blue; when put in an acid, it turns red. Red colored litmus paper when put in an acid stays red; in a base, it turns blue. Phenolphthalein is another commonly used indicator in liquid form. It is colorless in a neutral or acidic solution and turns red in an alkaline solution. (pH 8.3 to 10.0).

One measures the pH of natural waters to determine if it must be treated to bring it to an acceptable pH for human consumption. The pH of natural waters vary from pH 6 to 9 because of the substances dissolved in them.

SELF-TEST

1.	__________ is used to express the power of ionization of the hydrogen ion.	pH
2.	The pH scale runs from __________ to __________.	0, 14
3.	A pH of 13 shows a very __________ substance.	alkaline
4.	pH 3 shows a very __________ substance.	acidic
5.	A substance which is neutral has a pH of __________.	7
6.	__________ are substances which change color at various pH levels.	indicators
7.	Blue litmus paper turns __________ in lemon juice.	blue
8.	Red litmus paper turns __________ in milk.	red
9.	Phenolphthalein turns __________ when put in Borax.	red
10.	Natural waters can be acidic from what sources?	mine wastes ore dumps atmospheric CO_2

SOLUTIONS AND SUSPENSIONS

A solution is defined as a homogeneous mixture of two or more substances. What this means is that any one part of the solution is exactly like any other part of the solution.

A solution has two parts, the solute and the solvent. The solute is the substance which is dissolved. The solvent is that which dissolves the substance. When one puts salt in water a solution is formed. The salt is the solute and the water is the solvent.

There are various types of solutions. Gases mixed with gases are solutions. Air, for example, is a solution of oxygen dissolved in nitrogen. Gases can form a solution when they are put in a liquid. Carbon dioxide dissolved in water is a solution. Solids or liquids can dissolve in liquids to form solutions.

Solutions can be considered dilute or concentrated depending on the amounts of solvent. If there is a small quantity of solute in a given large amount of solvent, the solution is considered to be dilute. A concentrated solution is one in which there is a larger quantity of solute in a given solvent. For example, 5 g. of sodium chloride (NaCl) in a liter of water is considered to be a dilute solution. 25 g. of sodium chloride (NaCl) in a liter of water is a concentrated solution.

The terms, concentrated and dilute, are terms which do not show exactly how much of either solute or solvent is present. They are helpful to know when describing solution in general terms. The same holds true for the terms saturated, unsaturated, and supersaturated.

If soda ash (Na_2CO_3) is added to a liquid such as water to form a solution until the solution will hold no more, the solution is considered to be saturated. One can help a solvent dissolve more solute by raising the temperature of the solution. For example, if a liter of water will dissolve only 5 grams of soda ash (Na_2CO_3), it may dissolve 10 grams of soda ash (Na_2CO_3) if the water is heated. If the solution is slowly cooled to its original temperature, the soda ash (Na_2CO_3) may remain dissolved. This solution is considered to be supersaturated. The solution in this case has more of a solute dissolved in a given volume than it can hold.

As you can see, changes in temperature have an effect on solutions. As a general rule, liquids and solids are more soluble in a given solvent as the temperature is increased. Gases, on the other hand, are less soluble as the temperature is increased.

The freezing point of a liquid can be lowered or its boiling point raised if a substance is dissolved in it. For example, if one dissolves a 106 g. of soda ash (Na_2CO_3) in a liter of water, it will now freeze at 28.65° Fahrenheit instead of 32° Fahrenheit. The boiling point is raised from 212° Fahrenheit to 212.94° Fahrenheit.

Some substances do not dissolve in water and when the particles of these substances are very fine, they will not settle rapidly. This type of mixture is called a suspension. If the particles are allowed to remain in undisturbed water long enough, these particles will settle. Activated charcoal in water will create a suspension. Turbidity or cloudiness in water is often the result of suspensions.

The particles found in liquids of suspensions are called colloids. More will be said about colloidal suspensions in the next section of this module.

SELF-TEST

1. A homogeneous mixture of two or more substances is called a ________.	solution
2. The substance which is dissolved is called the ________.	solute
3. If more solute can be dissolved in a solution, the solution is said to be ________.	unsaturated
4. Gases are less soluble as the temperature is ________.	increased
5. Substances which do not dissolve in a solvent but remain as whole units make up a mixture called a ________.	suspension
6. Particles of a suspension are called ________.	colloids

COLLOIDS

We have mentioned suspensions briefly in the section on solutions. Let us now take a closer look at these suspensions or colloidal systems.

A colloidal system is made up of a particular medium in which very small particles are suspended. These particles may be gases, solids, or liquids. Likewise the medium may be gases, solids, or liquids. Examples of colloidal systems are dust particles suspended in air, fog, (water in air), muddy water (clay in water) and emulsions (liquid in a liquid) such as oil in water. In most cases colloidal particles are too small to be removed by filtering or by sedimentation.

These colloids have two properties which are of interest to us:
1. colloidal particle surfaces tend to become electrically charged, and
2. these surfaces can absorb other substances.

The surface area of colloid substances is tremendous. While each particle is small, there is a great number of them. One can compare the surface area of colloidal particles to the surface area of a basket full of peas and a basket full of oranges to see how much actual surface area exists. While an orange has more surface area than a pea because of its larger size, a basket full of peas would have more surface area than a basket full of oranges. This is because a basket can hold more peas than oranges. Therefore if one could remove the skins from the peas and oranges and lay them flat on a surface, the pea skins from the basket would cover more area than the orange skins from its basket. In a like manner, the surface area or "skin" of one colloidal particle is small but there are so many colloidal particles in a particular container that their surface area becomes tremendous.

This tremendous surface area along with the colloidal particles' ability to absorb other substances, explains why activated carbon (a colloidal system when put in water) is effective in removing taste and odor.

The electrical charge which forms on colloidal particles explains why colloids tend to remain suspended instead of settling out. The particles act like tiny magnets with one pole (the negative one) which continually repel each other.

In water treatment, one takes these particles out of suspension by a method called coagulation. In this process, one adds salts such as iron and aluminum salts, which bind the particles together. Both Al and Fe have positive charges which attracts and holds the negatively charged colloidal particles. These bonded molecules grow and become heavy enough to settle out.

As a result of the addition of coagulating chemicals, one can see large particles form in the coagulation basin and settle out. The large particles are called floc and the settling of this floc is called precipitation.

SELF-TEST

1. A __________ __________ is made up of a particular medium in which very small particles are suspended.	Colloidal system
2. The surface area of colloidal particles is __________.	large
3. Activated carbon removes __________ and __________.	taste, odor
4. Colloidal particles stay suspended in a medium because of the __________ __________ on them.	electrical charge
5. __________ takes these colloidal particles out of suspension. (A water treatment process).	coagulation
6. The large particles that appear after the addition of coagulating chemicals are called __________?	floc
7. The settling out of floc is called __________.	precipitation

WATER QUALITY

So far in this module, we have limited our discussion of chemistry to theory. We have also given some examples of how this theory applies to what you may be doing in your job e.g. softening, pH, etc. Let us now turn our attention to specific contaminates of water and how they effect water treatment. The allowable limits for the following contaminents are taken from the 1974, Safe Drinking Water Act (Public Law 93-523).

IRON (Fe)

Iron (Fe) in the water supply will stain plumbing fixtures and laundry. It can come from mineral contaminants in the earth the water has passed through, from iron casings and pumps or from a type of bacteria. This iron bacteria uses iron for its metabolism so it has a tendency to collect this metal. This organism when present in the water may create "red" water or clog water lines. Normally this bacteria can be controlled by chlorination. Iron dissolved in the water may be removed by oxidation, settling and filtration.

Some water supplies may be apparently clear but turn red upon standing. This phenomon is seen most commonly in ground water. While the red stain produced by this mineral is not harmful to the user, it is objectionable from an aesthetic point of view. Water containing more than 0.3 ppm is considered objectionable.

NITRATES (NO_3^-; NO_2^-)

Nitrates are known to cause a condition in babies called methemoglobinemia or "blue babies". It comes from feeding babies formula containing a high concentration of nitrates. It apparently does not effect adults.

High concentrations of nitrates in water usually indicates that the water is polluted from wasted of privies, cesspools and barnyards. If a high nitrate level is found in well water, it usually indicates that the well is improperly constructed.

A concentration of over 40 ppm nitrates is considered objectionable. There is no economical method of removing excess nitrates from the water. So it is important that water supplies are protected from contamination.

SULFATES (SO_4--)

Sulfates in waters not only cause hardness which forms scale in steam boilers or water heaters but will have a laxative effect. This last phenomenon is noted especially by infrequent users of water.

Concentrations in excess of 250 ppm will give the water an objectionable taste. Sulfates can be removed by softening.

CHLORIDES (Cl-)

Chlorides are commonly found in water and in concentrations less than 250 ppm can not be detected. In greater amounts the water may have a salty taste. High concentrations normally have no health significance (1800 ppm have been recorded in some areas of Missouri) but may not be suitable for infants. In addition to the salty taste, chlorides can also cause corrosion problems.

Soluble chlorides can not be economically removed from water. So it is important to protect water supplies from this contaminent.

FLUORIDES

Flourides when present in moderate amounts have been found to prevent tooth decay or cavities. In excess this mineral can cause teeth to turn brown.

In Missouri the optimum range for flourides has been established at 0.9 to 1.2 ppm. Since some Missouri waters naturally contain some flourides, its level in public water supplies is adjusted to the optimum level.

HARDNESS

Water hardness as discussed earlier in this module is caused by the presence of calcium and magnesium ions which effect the cleaning power of soap. It does not effect the potablity of water. These ions can be removed by softening.

OTHER CONTAMINENTS

In Table 4 are listed several other contaminents and their recommended maximum level.

TABLE 4

Contaminent	Recommended Maximum Level
Odor	3 Threshhold Odor Number
Manganese (Mn)	0.05 ppm
Foaming Agents	0.5 ppm
Copper (Cu)	1.0 ppm
Zinc (Zn)	5 ppm
Hydrogen Sulfide (H_2S)	0.05 ppm
Total dissolved solids	500 ppm
pH	6.5-8.5
Arsenic (As)	0.05 ppm
Barium (Ba)	1.0 ppm
Cadmium (Cd)	0.010 ppm
Chromium (Cr)	0.05 ppm
Lead (Pb)	0.05 ppm
Mercury (Hg)	0.002 ppm
Selenium (Se)	0.01 ppm
Silver (Ag)	0.05 ppm
Turbidity	One turbidity unit (TU) for one sample.

Contaminents and their recommended maximum level from the Safe Drinking Water Act (1974).

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. Basic Level Water Treatment Operator's Practices, AWWA, No. M18 Denver Co. pp 1-16.
2. Course in Basic Chemistry for Water and Wastewater Personnel, AWWA 121 pages.
3. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY pp. 45-75.
4. Operation of Wastewater Treatment Plants, California Water Pollution Control Association, Environmental Protection Agency, Sacramento, CA Chapter 14.
5. Safe Drinking Water Act. Information about this act can be obtained by writing to:

United States Environmental Protection Agency
1735 Baltimore
Kansas City, MO 64108

or the

AWWA
6666 W. Quincy Avenue
Denver, CO 80235

POST-EVALUATION (4 pts. each)

1. True or False
   - a. The pH is of no importance in the control of coagulation processes.
   - b. A compound is a substance of two or more chemical elements chemically combined.
   - c. Calcium is one of the constituents which causes hardness.
   - d. Dissolved minerals cause turbidity.
   - e. Matter is anything that occupies space, has weight and a shape.
2. Line is added to water for the purpose of:
   - a. killing bacteria
   - b. rendering the water easier to filter
   - c. to remove dissolved oxygen
   - d. to soften
3. A chemical often used as a coagulant is:
   - a. activated carbon
   - b. aluminum sulfate
   - c. quicklime
   - d. calcium bicarbonate
4. Elements that produce hardness in water are:
   - a. sodium, potassium
   - b. nitrogen, sulfur
   - c. calcium, magnesium
   - d. fluorine, oxygen
5. The chemical symbol for carbon monoxide is:
   - a. CO
   - b. CO_2
   - c. CO_3
   - d. all of these
6. What is the difference between a solution and a suspension?
7. Give the name of the following chemical substances:
   - a. Na
   - b. H_2SO_4
   - c. Fe
   - d. CO_2
   - e. $NaOH$
8. Which of the formulas is a strong base?
   - a. H_2SO_4
   - b. $NaOH$
   - c. NCl
9. Hydrochloric acid is:
   - a. HCl
   - b. H_2SO_4
   - c. $CaSO_4$

10. True or False.
    a. The pH is of no importance in the control of coagulation processes.
    b. The pH is lowered when alkali is added.
    c. Water with a pH of 6.0 has a greater concentration of hydrogen ions than a water with a pH of 7.0.
    d. The pH scale ranges from 1 to 10.
    e. All water which has a pH of 7.0 is neutral.

11. Neutrality on the pH scale is:
    a. 6.0
    b. 8.0
    c. 7.0

12. Define:
    a. Solvent
    b. Compound

ANSWERS

1. a. F
   b. T
   c. T
   d. F
   e. T
2. d
3. b
4. c
5. a
6. Solution has material dissolved in it, suspensions do not.
7. a. Sodium
   b. Sulfuric Acid
   c. Iron
   d. Carbon Dioxide
   e. Sodium Hydroxide
8. b
9. a
10. a. F
    b. F
    c. T
    d. F
    e. T
11. c
12. a. Solvent: A substance in which a solute is dissolved.
    b. Compound: A substance composed of two or more elements united chemically.

MODULE 3

SELF-INSTRUCTIONAL

Paul Hummel - NMSU

ANALYSIS PROCEDURE

PREREQUISITES: Module 2 - Basic Chemistry

DIRECTIONS: Take the self-evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the self-tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. Safety in the water treatment plant laboratory is (7 pts.)
   a. not important
   b. so-so
   c. very important

2. Acids and bases are corrosive to (7 pts.)
   a. human tissue
   b. wood
   c. glass
   d. a and b
   e. all of the above
   f. none of the above

3. Spilled Acids can be neutralized with (7 pts.)
   a. Sodium Chloride
   b. Saturated Boric Acid Solution
   c. Sodium Bicarbonate

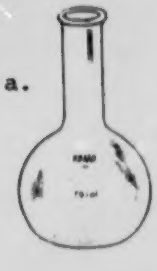
4. Safety goggles or eyeglasses are worn in the laboratory (7 pts.)
   a. to allow the operator to see better
   b. to protect the eyes from splashing chemicals
   c. all of the above
   d. none of the above

5. There are _____ basic types of fire extinguishers. (7 pts.)
   a. two
   b. three
   c. four
   d. five

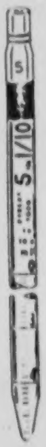
6. Samples taken for testing should be _____. (7 pts.)
   a. a representative sample
   b. a composite sample
   c. a grabbed sample
   d. a small sample

7. Identify the following equipment (7 pts. each, total 28 pts.)

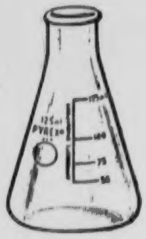
a.



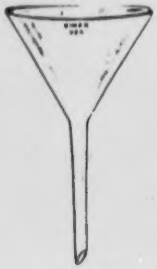
b.



c.



d.



8. A label on a chemical bottle should contain: (7 pts.)

   a. Chemical name
   b. Chemical formula
   c. Date and initials
   d. All of the above
   e. None of the above

9. The units of measurement employed in the lab are the: (7 pts.)

   a. English system
   b. Metric system
   c. Calvin system
   d. French system

10. Convert 50°F to °C. (7 pts.)

11. Define: (3 points each, total 9 pts.)
   a. Aliquot
   b. Blank
   c. Representative Sample

ANSWERS

1. C
2. D
3. C
4. B
5. C
6. A
7. a) Volumetric flask
   b) Graduated pipet
   c) Erlymeyer flask
   d) Funnel
8. D
9. B
10. 10°C
11. a) Aliquot: Portion of a sample.
    b) Blank: A bottle containing dilution water or distilled water, but the sample being tested is not added.
    c) Representative sample: A portion of material or water identical in content to that in the large body of material or water being sampled.

INTRODUCTION

This module will introduce you to the laboratory, laboratory procedures, and laboratory safety. It does not include the methods of running various water chemistry tests. These procedures can be found in the Standard Methods for Water and Wastewaters and will be explained to you by your instructors.

The most important part of the module is the first section on laboratory safety. Read it carefully and understand what it says. You may be able to prevent a serious accident if you follow the safety procedures outlined there.

The rest of the module is devoted to explaining various laboratory equipment and general laboratory procedures. An understanding of this material will make your job as a water chemist a little easier.

PERFORMANCE OBJECTIVE

When this module is completed, you will be able to show that you have mastered the following concepts:

1. Laboratory safety
2. Laboratory equipment identification and their care
3. Laboratory measurements including temperature conversions
4. Terms used in chemical tests

Mastery of this module will be shown by answering of the questions found in the Post-Evaluation with 70% accuracy.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you can understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

NOTE: READ THIS SECTION OF THIS MODULE CAREFULLY! KNOW WHAT TO DO IF A DANGEROUS ACCIDENT OCCURS! IT MAY SAVE A LIFE - YOURS!!!

LABORATORY SAFETY

As safety is important in the treatment plant, it is also very important in the laboratory. For example, you will encounter harmful acids and bases in testing procedures. You may also break glassware. These can lead to potentually dangerous situations if not handled correctly. Read this section of the module carefully and become thoroughly acquainted with what to do when accidents occur. In this way you will be prepared for any situation.

In some of the tests you will be doing, you will use acids such as H_2SO_4 (sulfuric acid), HCl (hydrochloric acid), and HNO_3 (nitric acid) and bases such as NaOH (sodium hydroxide), KOH (potassium hydroxide) and NH_4OH (ammonium hydroxide). These materials are extremely corrosive to human tissue, clothing, wood and cement. When using these chemicals, make sure to use glassware or polyethylene containers.

If you accidently spill acid, immediately dilute it with large portions of water. Neutralize the acid with sodium carbonate (Na_2CO_3) or bicarbonate ($NaHCO_3$). When the bubbling and foaming stops, clean up the neutralized material. If the spill happens on a bench top, you can dilute, neutralize and wipe it into a sink. If the spill occurs on a person, wash it off immediately with water. If it occurs on a face, wash it with large quantities of cold water. Make sure to report any accident to your supervisor.

Some bases such as ammonium hydroxide (NH_4OH) are extremely irritating to the eyes and respiratory system. So when using such chemicals, work with them under a laboratory hood with the fan going. If bases are spilled, wash the area with large quantities of water and use saturated boric acid solution to neutralize it. Always pipette bases as well as acids with a rubber bulb.

There are other substances such as a chlorine gas solution (Cl_2), carbon tetrachloride (CCl_4), nitric acid HNO_3), bromine (Br_2), chloroform ($CHCl_3$) and carbon disulfide (CS_2) which are irritating and harmful to humans.

Avoid inhalation and handle them under a hood.

Gases such as acetylene or hydrogen and liquids such as carbon disulfide, benzene, ethyl ether and acetone are explosive and highly flammable materials. Store these materials to prevent fire hazards. Do not use them near an open flame or exposed heating elements.

Broken beakers and flasks should be discarded. If a more expensive item is broken, set it aside for salvage if possible. If it is damaged beyond repair, discard it. Make sure to check with your supervisor before discarding any glassware or equipment.

When performing chemical tests, there are some safety procedures which you should use. These are listed below:

1. Wear Safety Goggles or Eyeglasses.
   Eyes must be protected from splashing chemicals and flying broken glass by wearing goggles at all times. During a reaction or while heating glassware, never look into the mouth of the beaker or test tube.
2. Wear Lab Coat or Apron and Protective Shoes.
   Protect clothing and body from corrosive chemicals. Tennis shoes or sandals are not acceptable.
3. Know Location of Safety Equipment.
   A first-aid cabinet, a fire extinguisher (see note at end of section), a fire blanket and an eye-wash fountain should be available. Know exactly where they are located and how to use them.
4. Toxic Fumes.
   Any test involving a dangerous or unpleasant volatile material should be performed in a hood or well-ventilated part of the laboratory.
5. Measuring Chemicals.
   Never handle chemicals with the hands. Always use a spatula. Do not drip liquid chemicals. Pour stock solutions into a small beaker, then into the graduate. Pipette from the beaker, not the stock solution bottle.

6. High Temperature.
   Use protective gloves or long handled tongs when using autoclave, hot plate, furnace or oven.
7. Wash Up.
   Always wash your hands after handling chemical containers and test apparatus.
8. Labels.
   Always label containers with name of material, concentration, date, and your initials. This will prevent accidents with acids, etc. in unlabeled beakers and also prevent use of wrong reagents in lab tests.

NOTE: There are four basic types of fire extinguishers and combinations of the basic types. These types are labeled A, B, C, and D and each can be used for only certain types of fires. (See Figure 1) Know which of these extinguishers are found in your laboratory and which fires they extinguish.

FIGURE 1

A Green	An extinguisher bearing this symbol can be used on paper, cloth, wood and other ordinary combustibles.
B Red	An extinguisher bearing this symbol can be used on gasoline, oil, grease, and other flammable liquids.
C Blue	An extinguisher bearing this symbol can be used on live electrical equipment.
D Yellow	An extinguisher bearing this symbol can be used on combustible metals.

NOTE: AN OUNCE OF PREVENTION IS WORTH A POUND OF CURE. PREVENT LABORATORY ACCIDENTS.

SELF-TEST

1. Goggles are worn to protect the __________.	Eyes
2. To neutralize acid spills use __________.	Sodium carbonate Sodium bicarbonate
3. To neutralize bases that are spilled use __________.	Saturated boric acid solution
4. Tests of dangerous smelling solutions such as a chlorine solution should be carried out __________.	Under a hood
5. Acetylene, benzene and acetone are __________ and __________ __________ material.	Explosive, Highly flammable

SAMPLING

It is very important that before you run a laboratory test, a representative sample be taken. If a sample is taken that is not representative, the results will be incorrect and therefore meaningless. For example, a sample collected at the surface of a reservoir will have little relationship to the water entering the intake. Therefore a test on the reservoir water at the surface may lead to different results than those obtained by testing the intake water.

When sampling a main, make sure to run water from the tap long enough to empty the service pipe of its water. Thus a representative sample of the water in the main will be obtained. If you wish to determine the amount of chlorine in newly chlorinated water, you should take your sample at a point where the chlorine has become completely mixed with the entire volume of water for a period of at least 10 minutes. The clear water well is the source from which filtered water is sampled.

The frequency of sampling will vary from plant to plant and must be determined on an individual basis. Water supplies from wells or large reservoirs will change in their characteristics much less than water from streams or small reservoirs. Many factors such as wind and run-off influence the quality of water found in smaller bodies of water. As a result, weekly samples may be sufficient to test these waters in some instances or it may be necessary to take samples more often. For control of chlorination, a minimum of daily or hourly samples may be needed. You should check with your supervisor or your local health engineer to find out how often you should sample the various processes in your plant.

Some samples must be tested within a certain length of time. If not, chemical changes will take place which will give unreliable results. Check with your STANDARD METHODS to determine how long a sample can be kept before the results become unreliable.

SELF-TEST

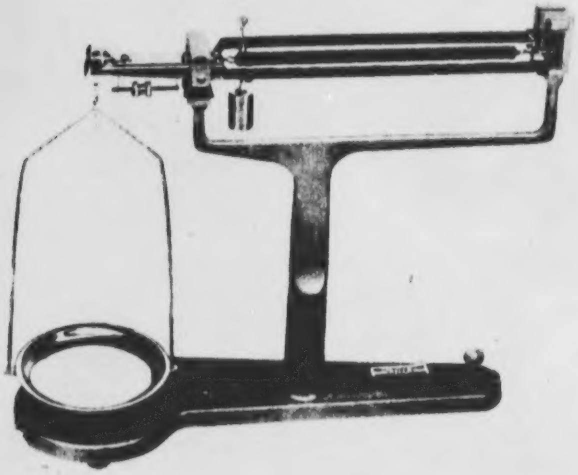
1. If a sample is not __________, test results will be incorrect.	Representative
2. Samples should be tested within a certain length __________ __________.	of time
3. How often should you sample water?	Varies from plant to plant

THE LABORATORY AND ITS EQUIPMENT

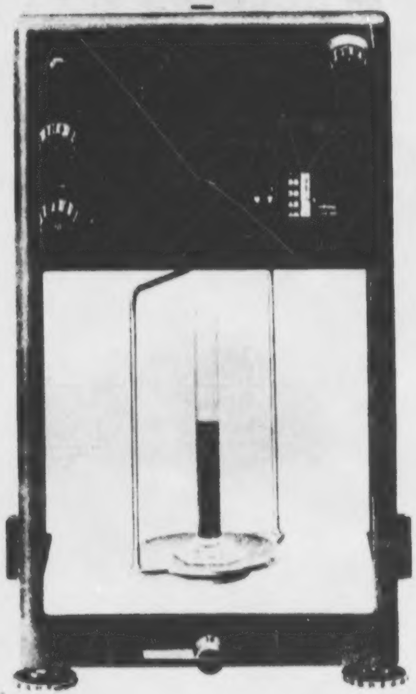
The laboratory in a water treatment plant is a place for precision work. Thus it must be kept clean and orderly. Each piece of equipment should have a particular space in the laboratory where it is kept and returned to when it is done being used. All chemicals should be clearly and properly labeled. Laboratory cabinets and drawers should not be used as a storage area for tools, supplies and miscellaneous equipment, nor should the laboratory be used as a kitchen or lunchroom.

WEIGHING EQUIPMENT

There are two types of balances found in the laboratory. The one used most commonly for routine tests is the rough balance. It can weigh up to a kilogram with an accuracy of 0.1 gram.



The other balance is an analytical balance. It is an extremely delicate instrument that can weigh up to 200 grams with an accuracy of 0.001 grams. Since this is a more accurate balance than the rough balance, it is used for preparing standard solutions. It should be treated with great care and you should become acquainted with the directions given in the instruction manual.



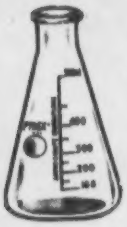
When using the analytical balance, ivory-tipped forceps should be used to move the weights from their box to the balance pan. This is important because oil and dirt on the hands will change the weights of the pieces of metal if they are moved by hand. These weights should be put on the counterbalance beginning with the heaviest weight and working down to the lightest one. Also remember to lift the beam from the knife edges when adding these weights so that the balance is not damaged. When the final weighing is being done, make sure to close the glass doors. This will ensure that air currents do not cause the pointer to weave.

When not using the balance make sure the balance beams and pans are removed from their knife-edge supports and the doors are closed. The weights should always be returned to their proper places in the weight boxes. The balance pans and floor of the case should also be kept clean with a camel's-hair brush, before and after using the balance.

GLASSWARE

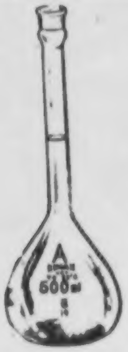
Laboratory glassware should be made of "pyrex". This is a specially treated heat-resistant type of glass. Polyethylene plastic while suitable for many laboratory operations will often melt in the presence of heat.

ERLENMEYER FLASK



The Erlenmeyer flask is a general purpose flask used for containing and mixing solutions. They range in capacity from 10 ml. to several liters.

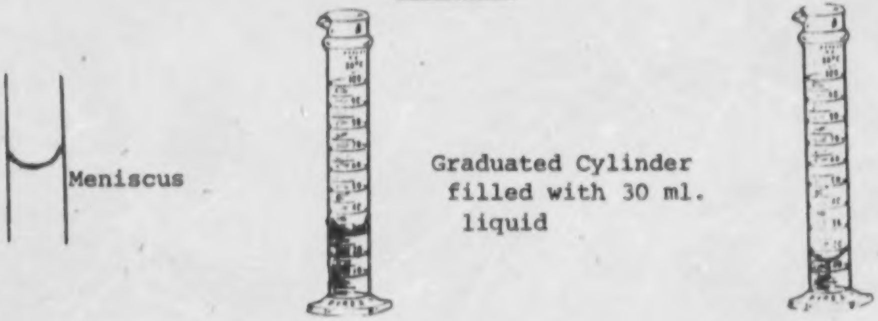
VOLUMETRIC FLASKS



Volumetric flasks have capacities ranging from 1 ml. to 2,000 ml. The ring etched around the neck shows when this capacity is reached. These flasks are used for the preparation and dilutions of standard solutions.

In order to determine when the correct volume of liquid is in the flask, one levels the meniscus bottom with the ring. The meniscus is seen when a liquid is put in a tube of glass. The upper surface of this liquid will curve. It is this curve which is called the meniscus. (See Figure 2). The readings of volumetric glassware such as flasks, graduates, burets and pipets, should always be taken at the bottom of the meniscus.

FIGURE 2

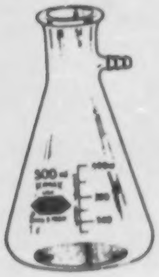


Meniscus

Graduated Cylinder filled with 30 ml. liquid

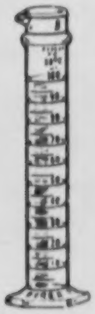
15 ml. liquid

FILTER FLASKS



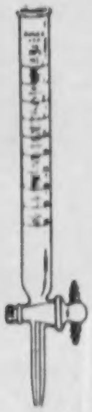
The vacuum filter flask is essentially an Erlenmeyer flask with a side-arm attachment to receive a vacuum hose. Filtration is accomplished by placing a filter funnel in the neck of the flask and drawing the liquid through with the aid of the vacuum.

GRADUATE



The most commonly used glassware found in the laboratory which is used for measuring liquids is the graduated cylinder. It is commonly called the graduate. It is available in sizes up to a liter. Unlike the volumetric flask which measures only the volume which the flask can contain; the graduate can measure a variety of volumes. A 10 ml. graduate is marked in fractions of a milliliter. Graduates from 15 to 250 ml. are marked in milliliters and sizes of 250 ml. or larger are marked at intervals of 5 or 10 ml.

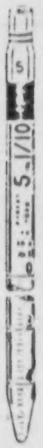
BURETS



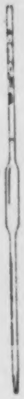
The buret is essential for several treatment plant tests. It is designed to deliver liquids in a controlled fashion, such that additions can be made dropwise or intermittently and the final volume delivered determined. The straight bore, and Teflon stopcock is recommended for general use. Burets with larger or smaller capacities can be obtained. Fill the buret by adding the liquid with aid of a funnel to the top with the stopcock closed. Fill it well above the 0 ml. mark. Then bleed out the tip so that the orifice through the stopcock and the tip are free of air bubbles. Continue bleeding until the meniscus at the top of the buret reads 0 ml. Dispense the liquid by grasping the stopcock with the left hand, leaving the right hand free to agitate the flask below. After the required volume has been dispended, read the meniscus. Notice that the values increase from top to bottom. The difference between the final buret reading and the initial buret reading will give the exact volume dispensed. By this method, it is not necessary to refill between each operation. Simply calculate the difference in buret reading as you continue to dispense the liquid. However, be careful not to dispense below the 50 ml. mark.

There are some precautions which need to be taken to ensure proper use of the buret. Air bubbles should not be present in the liquid in the buret. These can be eliminated by gently tapping the side of the buret. The stopcock should not leak and should always be well lubricated. The buret should also be clean to avoid dirt particles which may give false readings or clog the hole in the stopcock. All these precautions will present inaccurate measurements of the amount of liquid used from the buret.

PIPET



Graduated



Transfer

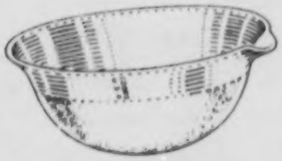
These are two types of pipets. The first called a transfer or volumetric pipet will measure only the amount of liquid contained by the pipet. The other type called a graduated pipet will measure any volume up to the designated capacity of the pipet.

A pipet is filled by suction. The tapered end of the pipet is placed in the liquid to be measured. Suction is placed on the pipet tube and the liquid is drawn into the tube. Liquid is then allowed to leave the tube until the desired volume is reached. The pipet is then put in the reaction vessel and the liquid is allowed to flow freely into it. The last drop should remain in the pipet.

BEAKERS

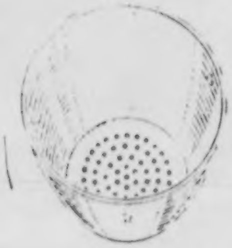
Beakers are the most common non-volumetric piece of glassware and range in size from 1 ml. to 4000 ml. Although they do have graduations, they should not be used to measure accurate volumes.

EVAPORATING DISHES



Porcelain evaporating dishes are used to dry chemical samples. Sizes of 70 and 150 ml. capacity are recommended. Sufficient number to handle several samples each day should be on hand.

GOOCH CRUCIBLE



The Gooch crucible is used in solids determination. The 35 ml. size is recommended.

BUCHNER FUNNELS

Porcelain Buchner funnels are used in solids determinations. The 80 mm. and 115 mm. diameter size would be recommended.

CARE OF GLASSWARE

Glassware should be kept clean at all times. After each use, glassware should be cleaned with a good household non-polluting detergent. It should be thoroughly rinsed with tap water at least four times; then rinsed at least three times with distilled water. Glassware should be allowed to air dry.

A solution which can be used to clean extremely dirty or hard to clean glassware is a chromic acid solution. This is made by placing 40 to 50 g. of potassium dichromate ($K_2Cr_2O_7$) in a glass or rubber stoppered glass bottle and carefully pouring in 1 liter of concentrated sulfuric acid (H_2SO_4). This solution can be used until there is a loss of color or when it turns green. THE CHROMIC ACID SOLUTION SHOULD BE HANDLED WITH EXTREME CAUTION. It is very powerful and will attack human flesh as well as cotton, wool and most synthetic fibers. Therefore the use of this solution should be restricted to the most difficult cleaning problem.

OTHER LABORATORY EQUIPMENT

pH METER

The pH meter should have a range of 0 to 14 pH, and deliver ± 0.1 pH accuracy. This instrument is used to adjust pH of solutions, titrations, and other procedures requiring some degree of accuracy.

pH TEST PAPER

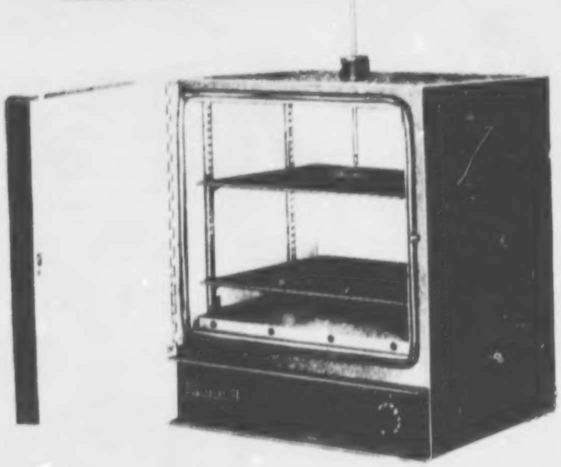
pH test paper is a convenient tool for getting a rough check of the pH very quickly. It can be obtained in nearly any range. For general use, a range of 1 to 11 pH and an accuracy of 0.5 is adequate.

The test paper is treated with an indicator which will change color when moistened. Distinct color changes occur over the entire range of pH. To determine the pH of a solution with pH test paper, obtain a drop of the solution with a stirring rod and apply it to a piece of the test paper. The paper will change color immediately. Determine the pH by comparing to the color chart on the dispenser.

SPECTROPHOTOMETER

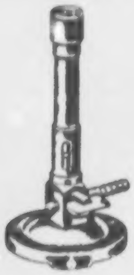
The spectrophotometer is required for color intensity determination on several tests. The instrument should have the capacity to work in the range of 400 - 700 nm.

DRYING OVEN



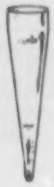
The drying oven is used to dry crucibles, dishes, filter paper, chemicals and glassware. It should have a heating capacity of up to 150 C. USE CAUTION BECAUSE OF HEAT. HANDLE MATERIAL WITH TONGS OR GLOVES.

BUNSEN BURNER

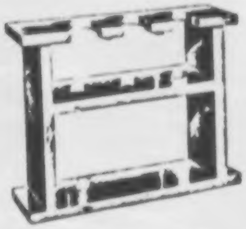


The burner is used as a source of heat for boiling and to sterilize equipment. The burner should be compatible with the type of gas available for fuel.

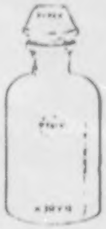
Shown below are pictures of other pieces of equipment commonly found in a well stocked water chemistry laboratory.



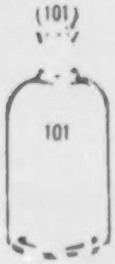
Cone,
Imhoff
(IM-hoff)



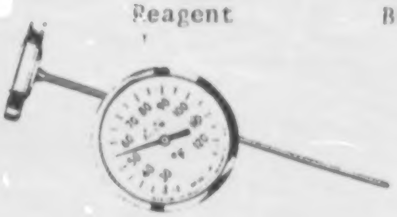
Cone Support



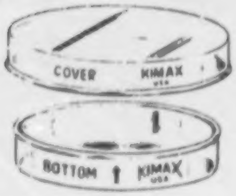
Bottle,
Reagent



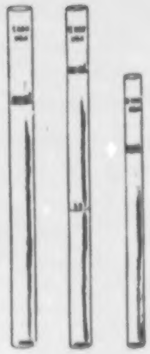
Bottle,
BOD



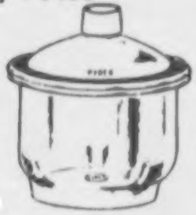
Thermometer, Dial


COVER
KIMAX
BOTTOM
KIMAX

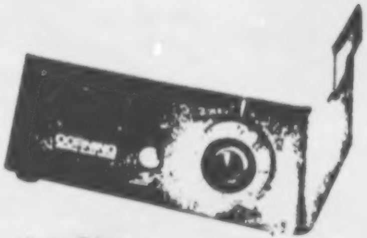
Dish, Petri



Color Comparison
Tubes, Nessler

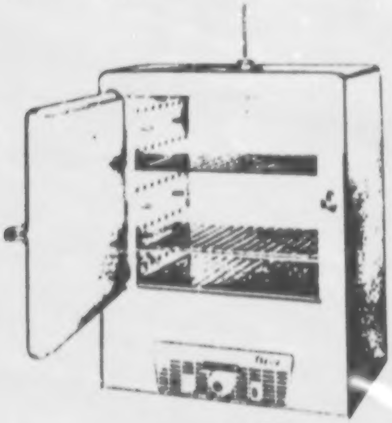


Desiccator
(DES-ick-kay-tor)

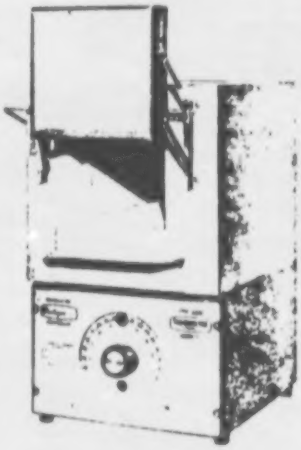


Hot Plate

103°

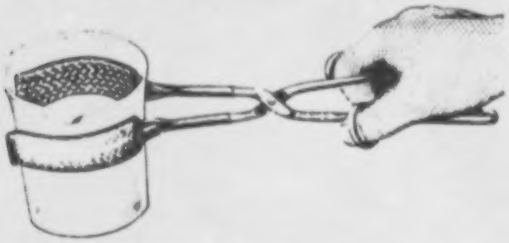


Oven, Mechanical Convection

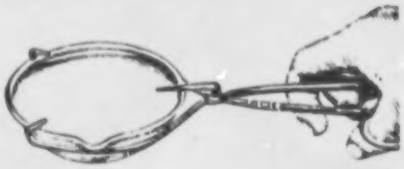


Muffle Furnace, Electric

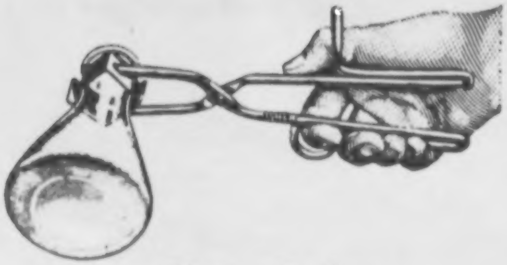
Shown below are pictures of other pieces of equipment commonly found in a well stocked water chemistry laboratory



Clamp, Beaker, Safety Tongs

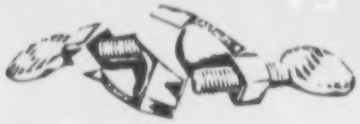


Clamp, Dish, Safety Tongs

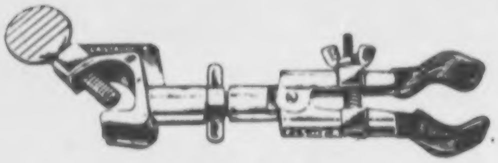


Clamp, Flask, Safety Tongs

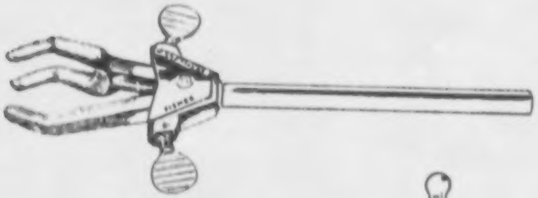
Clamp, Test Tube



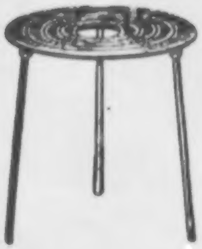
Clamp Holder



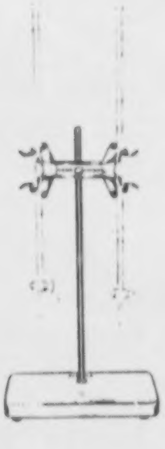
Clamp, Utility



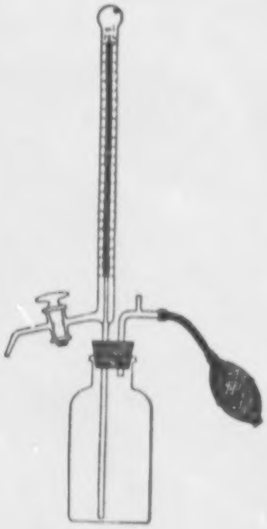
Clamp



Tripod, Concentric Ring

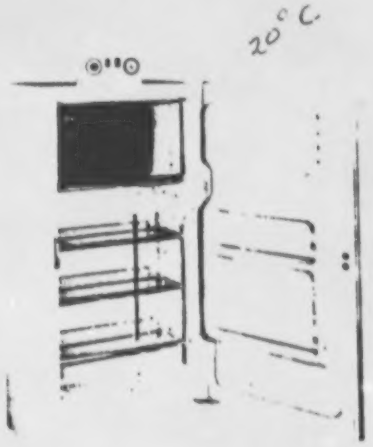


Support, Buret & Buret Clamp

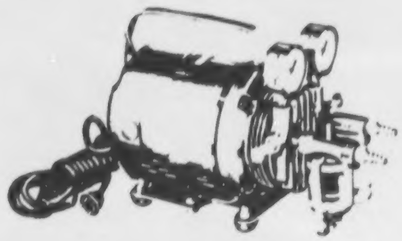


Buret Automatic

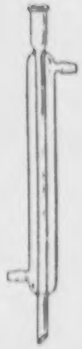
Shown below are pictures of other pieces of equipment commonly found in a well stocked water chemistry laboratory



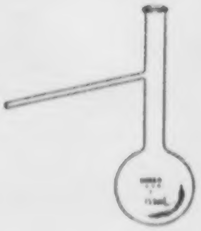
BOD Cabinet



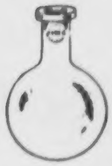
Pump, Air Pressure & Vacuum



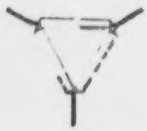
Condenser



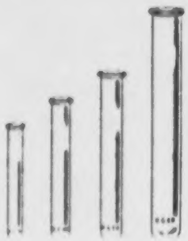
Flask,
Distilling



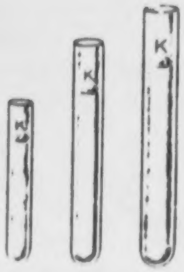
Flask,
Boiling
Round Bottom
Short Neck



Triangle
Fused



Test Tube



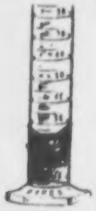
Culture Tube
Without Lip

SELF-TEST

1. Laboratory glassware should be made of __________.

Pyrex

2. How much liquid is in the container?

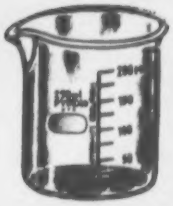


25 ml.

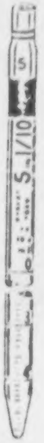
3. A __________ __________ solution is used to clean hard to clean glassware.

Chromic Acid

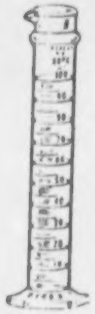
4. Identify:



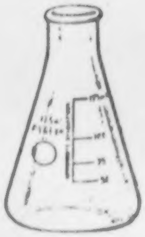
a.__________



b.__________



c.__________



d.__________

a. Beaker
b. Pipet
c. Graduate
d. Erlenmeyer Flask

DISTILLED WATER

All solutions used in the testing procedures should be made from distilled water. This water should be free from carbon dioxide (CO_2), residual chlorine and chloride. An efficient still or mixed-bed ion exchanger will provide a satisfactory grade of distilled water.

STANDARD SOLUTIONS

Concentration or strength of a reagent is indicated by the word normal (N). The use and calculation of normality is explained in another module. (See Chemistry Module). The important thing to remember now is that, for example, 50 ml. of a 0.1 N sulfuric acid solution (H_2SO_4) will neutralize exactly 50 ml. of a 0.1 N sodium hydroxide solution (NAOH). An 1 N sulfuric acid solution (H_2SO_4) is a different and stronger concentration of the acid.

Reagents of known strengths can be purchased from supply houses. Reagents can also be prepared and standardized according to STANDARD METHODS. Chemicals labeled "ACS grade", "primary standard grade", or "analytical reagent grade" should be used to obtain the best results.

COLORIMETRIC DETERMINATIONS

When making color comparison tests, it is best to place the samples in matched tubes. They should be of the same size and have the same length of viewing path. The comparisons should be made while looking directly down into the tubes while holding them over a white surface. If the color is to be developed directly in the tubes, the contents of the tubes must be thoroughly mixed.

Permanent standards for color and turbidity can be obtained from supply houses. These are of two types. They can be the disk type containing a wheel of small colored glasses or they can be the slide type which contains liquid standards in glass ampules.

Another way of determining color intensity is through the use of a photometer. In this method, the standard and the sample are placed in the appropriate slots in the instrument. From the reading on the disk, one can determine the color intensity of the sample. Instructions for the photometer and permanent standards should be read and thoroughly understood in order to obtain the best results.

LABELS

When a chemical or a piece of equipment is used for a specific analysis, it should have some type of identification. When you prepare a chemical from a stock container (purchased from a supply house), you must identify that chemical properly. The stock container will have all the necessary information on its label. A general way for labeling chemical containing bottles is as follows:

Chemical Name
Chemical Formula
Concentration
Date Initials

For example:

Sulfuric Acid
H_2SO_4
10% by volume
7/22/78 JTD

Beakers and flasks can be labeled on the hexagon space of ground glass found on them. A lead pencil should be used for this type of marking. Grease pencils are primarily used for test tubes. It should be noted that grease pencil markings will readily rub off.

UNITS OF MEASUREMENT

In laboratory examination of water, units of measurement are employed that are more convenient than those in everyday use. This is the metric system (See the Mathematics Module for further explanation of this system.)

You have already studied the metric system and how to convert the English system to the metric system. One unit of measurement that you have not studied is the temperature units.

In the laboratory, temperature is measured in the centigrade scale. In this scale 0 C is freezing (32°F) and 100°C is boiling (212°F), Centrigrade degrees is abbreviated °C; Fahrenheit is abbreviated °F. To convert Fahrenheit degrees to Centigrade degrees, the following equation can be used.

$$\text{Degrees Centigrade} = \frac{\text{Degrees Fahrenheit} - 32}{1.8}$$

To figure degrees Fahrenheit from degrees Centigrade:

$$\text{Degrees Fahrenheit} = \text{Degrees Centigrade} \times 1.8 + 32$$

For example: $45^\circ F = ?^\circ C$

$$^\circ C = \frac{45^\circ F - 32}{1.8}$$

$$^\circ C = 7.2^\circ$$

$7.3^\circ C = ?^\circ F$

$$^\circ F = 7.3^\circ \times 1.8 + 32$$

$$^\circ C = 45^\circ F$$

SELF-TEST

1. To convert $50^\circ F$ to $\underline{?}^\circ C$.

a. The formula for finding $^\circ C$ is _________?	$^\circ C = \frac{^\circ F - 32}{1.8}$
b. Substituting $50^\circ F$ in the equation, the formula now looks like __________.	$^\circ C = \frac{50 - 32}{1.8}$
c. The answer is __________.	$10^\circ C$

TERMS

The following are terms that you will encounter in reading the instructions for various tests. (Taken from Operation of Wastewater Treatment Plants, Chapter 14).

Aliquot: portion of a sample

Ambient Temperature: Temperature of the surroundings

Blank: A bottle containing dilution water or distilled water, but the sample being tested is not added. Identical tests are frequently run on a sample and a blank and the difference compared.

Buffer: A measure of the ability or capacity of a solution or liquid to neutralize acids or bases. This is a measure of the capacity of water for offering a resistance to changes in the pH.

Composite Samples: Samples collected at regular intervals in proportion to the existing flow and then combined to form a sample representative of the entire of flow over a given period of time.

Distillate: In the distillation of a sample, a portion is evaporated; the part that is condensed afterwards is the distillate.

End Point: Samples are titrated to the end point. This means that a chemical is added, drop by drop, to a sample until a certain color change (blue to clear, for example) occurs which is called the end point of the titration. In addition to a color change, an end point may be reached by the formation of a precipitate or the reaching of a specified pH.

Flame Polished: Sharp or broken edges of glass (such as the end of a glass tube) are flame polished by placing the edge in a flame and rotating it. By allowing the edge to melt slightly, it will become smooth.

M or Molar: A molar solution consists of one gram molecular weight of a compound dissolved in enough water to make one liter of solution. A gram molecular weight is the molecular weight of a compound in grams. For example, the molecular weight of sulfuric acid (H_2SO_4) is 98. A 1M solution of sulfuric acid would consist of 98 grams of H_2SO_4 dissolved in enough distilled water to make one liter of solution.

N or Normal: A normal solution contains one gram equivalent weight or a reactant (compound) per liter of solution. The equivalent weight of an acid is that weight of a compound which contains one gram atom of ionizable hydrogen or its chemical equivalent. For example, the equivalent weight of sulfuric acid (H_2SO_4) is 49 (98 divided by 2 because there are two replacable hydrogen ions.) A 1N solution of sulfuric acid would consist of 49 grams of H_2SO_4 dissolved in enough water to make one liter.

Oxidation: is the addition of oxygen, removal of hydrogen, or the removal of electrons from an element or compound.

Reagent: A substance which takes part in a chemical reaction that is used to measure, detect, or examine other substances.

Representative Sample: A portion of material or water identical in content to that in the larger body of material or water being sampled.

Titrate: To titrate a sample, a chemical solution of known strength is added on a drop-by-drop basis until a color change, precipitate, or pH in the sample is observed (end point). Titration is the process of adding the chemical solution to completion of the reaction as signaled by the end point.

SUGGESTED READING

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. Course in Basic Chemistry for Water and Wastewater Personnel, Sponsored by Michigan Section AWWA, Michigan Water Pollution Control Association and Michigan Department of Public Health, pp. 69-92.
2. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY, pp. 99-114.
3. Manual of Water Utility Operations, Texas Water Utilities Association, Austin, TX, pp. 269-337.
4. Operation of Wastewater Treatment Plants, California Water Pollution Control Association, Environmental Protection Agency, Sacramento, CA Chapter 14.
5. Standard Methods for the Examination of Water and Wastewater, 13th Edition, American Public Health Association, AWWA, Water Pollution Control Federation, NY, pp. 3-48, pp. 367-369 (for module); entire book for methods of running specific tests.
6. Simplified Procedures for Water Examination, Laboratory Manual, AWWA No. M1a, Denver, CO, pp. 1-16. (Rest of book gives specific test procedures.)
7. Basic Level Water Treatment Operator's Practices, AWWA No. M18, Denver, CO, pp. 74-82.

POST-EVALUATION (4 pts. for each question except Question 1; worth 40 pts.)

1. True or False
   a. Safety is not important in the laboratory.
   b. Spilled basic solutions can be neutralized by a saturated boric acid solution.
   c. Sandals can be worn when performing chemical tests.
   d. In sampling a main, the water in the service pipe should not be allowed to run longer than 30 seconds before sampling.
   e. Laboratory facilities can be used as a kitchen.
   f. An analytical balance is used for making up standard solutions.
   g. The most commonly used glassware found in the laboratory for measuring liquids is the graduated cylinder.
   h. Beakers can be used to accurately measure volumes.
   i. Color intensity can be measured by means of a photometer.
   j. Chemical containers need not be labeled.

2. If an acid or base is spilled, the first thing you do is:
   a. neutralize the material
   b. wash it into the sink
   c. dilute it with large quantities of water

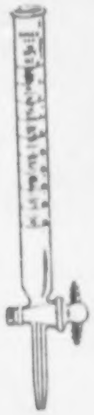
3. Ethyl ether and acetone are:
   a. acids
   b. bases
   c. smell bad
   d. explosive and highly flammable

4. Newly chlorinated water should be sampled:
   a. immediately
   b. at a point where it was well mixed for 10 minutes
   c. in the clear well
   d. after 20 minutes

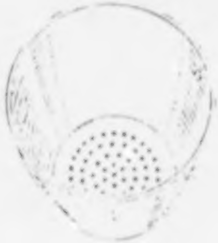
5. The frequency of sampling for most tests is:
   a. every 30 minutes
   b. every 60 minutes
   c. weekly
   d. varies from plant to plant and depends on the type of test being performed

6. Identify the following pieces of equipment:

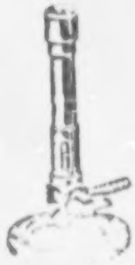
a.



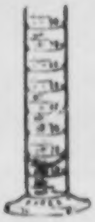
b.



c.



7. How much liquid is the graduated cylinder holding?



8. Convert 100°F to °C.

9. Define the word Normal (N).

ANSWERS

1. a. F
   b. T
   c. F
   d. F
   e. F
   f. T
   g. T
   h. F
   i. T
   j. F

2. c

3. d

4. b

5. d

6. a) Buret
   b) Gooch crucible
   c) Bunsen burner

7. 15 ml.

8. 37.8°C

9. Normal (N): A normal solution contains one gram equivalent weight of a reactant (compound) per liter of solution.

MODULE
4

SELF-INSTRUCTIONAL
Paul Hummel - NMSU

MICROBIOLOGY

PREREQUISITES: None

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. True or False (5 pts. each)
    a. Microbiology is the study of living organisms, their habits, food requirements and general life processes.
    b. The presence of algae in a water supply will cause disease.
    c. All viruses can not be seen with a light microscope.
    d. Algae can change the hardness and pH of water.
    e. Taps used for obtaining samples for bacteriological testing should not be flamed.
    f. Bacteria are plankton.
2. The resting stage in the bacteria life cycle is called a : (10 pts.)
    a. Flagella
    b. Spore
    c. Cilia
    d. Nucleus
3. Which of the following diseases are not caused by bacteria: (10 pts.)
    a. typhoid fever
    b. cholera
    c. measles
    d. dysentary
4. Which of the following tests is used to determine how much bacteria is found in the water: (10 pts.)
    a. Membrane Filter Method
    b. Sedimentation Tube Count Method
    c. Fisher Sub-sizer Method
5. Viruses cannot cause which disease shown below: (10 pts.)
    a. Tuberculosis
    b. Poliomyelitis
    c. Infectious hepatitis
6. The minimum number of samples which have to be taken for bacteriological testing is based on: (10 pts.)
    a. The capacity of the plant
    b. The type of raw water used as a source
    c. The population of the community the plant serves
7. Which of the following is not one of the steps taken in sampling a pumping station for bacteria. (10 pts.)
    a. Open the tap to flush it clean
    b. Make sure the tap is directly connected to the main which is to be sampled
    c. Fill the bottle without splashing
    d. Remove the bottle cap and place it on a clean surface
8. Which of the following departments has charge of policing water quality standards in Missouri: (10 pts.)
    a. Department of Health
    b. Department of Natural Resources
    c. Department of Education
    d. Department of Environmental

ANSWERS

1. a. F
   b. F
   c. T
   d. T
   e. F
   f. F
2. b
3. c
4. a
5. a
6. c
7. d
8. b

INTRODUCTION

When one studies living organisms, their habits, food requirements and general life processes, one is involved with the science of biology. This field encompasses a large number of organisms, since plants and animals are included in the term "living organisms." Most scientists specialize in one particular aspect of biology such as botany, zoology, entomology or limnology.

This module deals with one of these specific fields called microbiology, or the biology of microorganisms. These are plants and animals which are too small to be seen with the naked eye. Many can be seen with ordinary light microscopes; others are so small, that one can not see them even with the aid of the light microscope. These must be viewed with a special microscope called an electron microscope.

This module will deal specifically with two types of microorganisms called bacteria and viruses. A section in this module will deal with organisms not considered to be microorganisms but are never the less important in the biological examination of water. These aquatic organisms include plankton, algae, protozoa, higher aquatic plants and insects.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the following concepts:

1. Knowledge of the types of microscopic plants and animals found in water including:
    a. life histories
    b. their effects on water quality
    c. diseases caused by them
2. The Safe Drinking Water Act
3. Missouri Standards

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

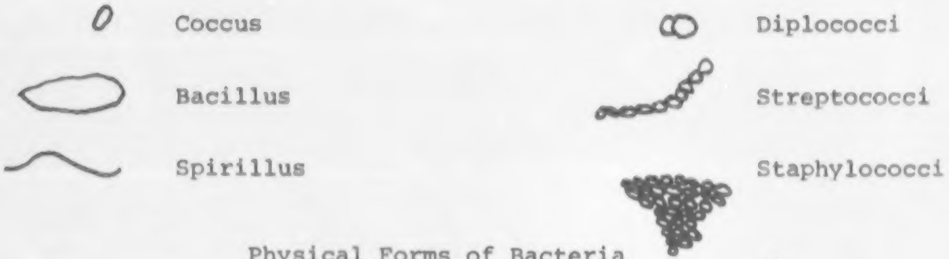
BACTERIA

While various kinds of microorganisms are found in water, the most important group from the standpoint of public health are the bacteria. Many are harmless and of no interest to us other than how they get into the water. Others are important because they can cause disease in the persons consuming the contaminated water, and, in addition, can cause taste and odor problems.

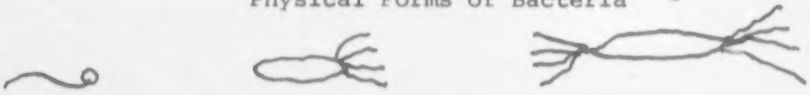
Bacteria are the simplest form of plant life in the water. They consist of single cells which cannot be seen with the naked eye. A typical bacteria cell is rod shaped and so small that 13,000 or such cells lying end to end would measure only one inch.

The bacteria cell, despite its small size, is extremely complex. It contains various bodies vital to the cells function, surrounded by a rigid membrane. Some bacteria have certain features not common to all of them. For example, some have structures called flagella. These are hair-like apendages which can vary from one to many and their location can vary from one end to both ends or even to the entire parameter of the cell wall. Some bacteria do not have flagella. (See Figure 1).

FIGURE 1



Physical Forms of Bacteria



Various Forma of Flagella

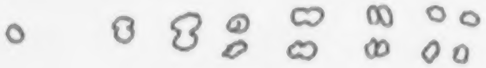
Taken from Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health.

Some bacteria can form structures called spores. These are "resting stages in the life of the cell." These form when there is a lack of food, lack of sufficient moisture and unusual temperature conditions. The bacteria cell in this stage of life cannot reproduce, but are more resistant to destruction than normal cells, thus the survival of the organism is insured. If the conditions become favorable, the spore becomes a normal cell again. This ability to produce spores can give water treatment plant operators problems. This is because this stage in a bacteria life cycle is highly resistant to destructive agents. Heat and chemicals will not kill it. Therefore, when water id disinfected by means of chlorination, a chlorine residual should be left in the water. This residual will kill any spores that become normal cells in the distribution system.

Bacteria have different shapes depending on their species. There are three general shapes - round, rod-shaped and curved. The round-shaped bacterial are cocci. Rod-shaped are named bacilli and curved-shaped are called spirilla. (See Figure 1).

Reproduction in bacteria takes place when environmental conditions are favorable. This is accomplished by a process called fission. In this process, the cell first becomes constricted usually near the center. This constriction gradually progresses until the cell divides in two to produce two new cells. (See Figure 2).

FIGURE 2



Reproduction of Bacteria

Taken from Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health.

If the conditions are favorable for reproduction, a bacteria cell can divide approximately every twenty or thirty minutes. As you can see, within a few hours many million bacteria cells could be produced.

The actual population of bacteria is controlled, however, by lack of food or poisons (as a result of waste products from other bacteria). Therefore, while populations of bacteria can be potentially great, in actuality there is not as many produced as one would think.

All water, even distilled water, contains sufficient food or nutrients which allow bacteria to grow. The only way to obtain water free from bacteria is to treat it with chemicals such as chlorine (Cl_2) or by heating the water.

One can say that all natural waters are contaminated with bacteria. These feed on the organic matter present in the water. This organic matter can come from the soil the water passes over, manure from animals, dead plants and animals, wastes from human activities such as garbage, and healthy plant and animal tissues.

This organic matter from human activities are of greatest interest to us. This is more commonly called pollution or sewage and the bacteria found in polluted waters may carry bacteria harmful to man.

Those bacteria which are harmful to man are called pathogens. Non-harmful bacteria are called non-pathogenic.

There are at least five diseases of pathogenic bacterial origin transmitted to man through polluted water. These are typhoid fever, paratyphoid fever, dysentary, cholera and non-specific diarrheal infections.

While it would seem that the safest course of action is to examine the water for all the organisms which cause these diseases, this is impractical. Most of them are very hard to isolate from the water and require a great amount of time to perform the necessary tests. It is much more practical to examine the water for the presence or absence of organisms specifically found with sewage. A group of bacteria (called coliforms) normally found in the intestines of humans and animals is always present when sewage-contaminated water is found. Therefore, it is this group of bacteria which the water treatment plant operator tests for to see if the water may be contaminated.

According to *Standard Methods for the Examination of Water and Wastewater* published by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation, the definition of the coliform group of bacteria is as follows: "The coliform group includes all of the aerobic and facultative anearobic, Gram-negative, non-spore-forming, and rod-shaped bacteria which ferment lactose with gas formation within 48 hours at 35°C." Since some of the terms used in this definition may be unclear, an explanation of them follows.

Aerobic: the ability to live in an oxygen rich atmosphere.

Facultative Anearobic: the ability to live in the absence of oxygen.

Gram-negative: refers to a technique of staining bacteria. Bacteria will either be stained or not. Coliform bacteria are not stained.

"Ferment lactose with gas formations": Lactose is a type of sugar. Some bacteria use this sugar to form a gas. The process of changing sugar to gas is called fermentation. The coliform bacteria change sugar to a gas within 48 hours at a certain temperature. This separates the coliforms from other bacteria which also use fermentation but at a slower rate.

There are two ways of determining whether water contains coliform bacteria. These are the multiple fermentation tube method and membrane filter method. An explanation of these techniques can be found in *Standard Methods for the Examination of Water and Wastewater*.

SELF-TEST

1. Bacteria are plants or animals?	plants
2. __________are "resting stages" in the life of the bacterial cell.	spores
3. Bacilli is the term used to describe _________ shaped bacteria.	rod
4. Bacteria feed on organic material from __________, ___________, ___________, __________ and ____________.	soil, manure, dead organisms, human activities, and healthy organisms tissues.
5. Five diseases of bacterial origin are:	typhoid fever paratyphoid fever dysentary cholera diarrheal infections
6. A water treatment plant operator examines the water for what group of bacteria?	coliforms
7. Two ways of testing for these bacteria are:	multiple fermentation tube method membrane filter method

VIRUSES

The smallest microorganisms known to man are the viruses. The largest of the viruses can just about be seen with the best light microscope. Most of them however are much smaller. Since they are so small these organisms pass freely through the openings of most filters. Only special filters made of collodion film will isolate them.

All forms of life are affected by viral diseases. Thus viruses are segregated into groups on the basis of the type of organisms they infect. There are plant viruses, animal viruses and bacterial viruses.

Since viruses can affect so many organisms, it is possible to find viruses under almost any environmental condition possible. They are found in the air, soil and in diseased plant and animal tissue. Of course they are also found in water.

Viruses are very hardy. Chlorine, for example, will destroy viruses only when it is in direct contact with the viral particle in a higher concentration and for a longer time than it takes to kill bacteria. A concentration of 0.2 - 0.3 ppm of free residual chlorine will destroy bacteria in 10 minutes at a pH of 7. For the same amount of chlorine, it requires 30 minutes of contact time to kill completely all viruses in a sample.

Viruses which cause infectious hepatitis and poliomyelitis have been isolated from sewage and streams polluted with sewage. Their numbers though appear to be less than the number of bacteria under the same conditions.

SELF-TEST

1. __________ are the smallest micro-organisms known to man.	viruses
2. True or false. Chlorine will kill viruses easily.	false
3. Two water borne diseases caused by viruses are __________ and __________.	infectious hepatitis poliomyelitis

OTHER SIGNIFICANT AQUATIC ORGANISMS

There are other organisms found in water that are not classified as microorganisms but are of interest to water plant operators. These are easily separated from water by simple sand filtration. These organisms include plankton and insects.

Plankton is a general term used to describe animal and plant life found floating or drifting in bodies of water. These organisms are invisible or barely visible to the naked eye. They can produce the tastes, odors, turbidity and colors characteristic of some waters. Some plankton species are also poisonious to animals. Groups of animals and plants found in plankton are the algae, fungi, and protozoa.

Algae are green plants requiring sunlight and the proper temperature, and chemicals for growth. While they are microscopic in size, they can cover an entire surface of a body of water if the conditions are right. This phenomena is called a "bloom."

Algae affect water quality in many ways. Some algae such as *Microcystics*, *Hydrodictyon*, *Mallomonas*, *Aphanizomenom* and *Synura* give water a disagreeable taste and odor. These odors can be described as fishy, earthy, musty, grassy, cucumber and septic. Tastes are generally described as sweet or bitter. Sand filters,both rapid and slow, can clog quickly by abundant growths of these plants. Algae can also cause some important changes in water chemistry. Through the process of living, they can change the pH and hardness of water. If large quantities of these organisms are present, the hardness of the water decreases and the pH rises during the day. This process reverses during the night. Thus, the rate and effectiveness of coagulation can be influenced, which in turn can cause a reduction in the flow in influent channels and can increase the amount of sludge to be disposed. Large amounts of plankton organism may also harbor and protect some pathogenic bacteria from the action of chlorine. So, the water treatment plan operator must carefully monitor the levels of hardness and pH, 24 hours a day to determine proper treatment levels.

Fungi are plants but unlike algae are not green. Some common fungi are yeasts and molds. Some species can clog filter underdrains and piping.

Protozoa are single cell organisms that require oxygen and organic food. These organisms have characteristics of plants and animals. They can impart disagreeable tastes and odors to water. One type of protozoa can transmit a disease called amebic dysentary to humans through polluted water.

Insects and large plant forms are other forms of life found in water. For now it is only necessary to know that these organisms can clog filters and produce taste, odors and colors in the water. More seriously, consumers become angry if some of these appear in their tap water, especially the insects.

SELF-TEST

1. __________ is a general term used to describe a group of animal and plant life found floating or drifting in bodies of water.	plankton
2. A __________ is when an entire section of a body of water is covered by algae if the conditions are right.	bloom
3. In what ways do algae affect water quality? (2 ways)	They change the hardness and pH. They produce disagreeable odors.
4. __________ can clog underdrains of filters and piping.	fungi

WATER QUALITY STANDARDS

We have mentioned in a previous section two ways of examining water for microorganisms. The details of these tests can be found in Standard Methods for Examination of Water and Wastewater. So, instead of considering the specific steps of these tests, let us look at Missouri and the Environmental Protection Agency requirements for taking samples and maximum allowable limits for bacteria.

ENVIRONMENTAL PROTECTION AGENCY WATER QUALITY STANDARDS

In 1974, Public Law 93-532, the Safe Drinking Water Act went into effect. This law states the minimum number of samples which must be collected each month from the distribution system. This required number of samples is based on the population served. A chart of the minimum number of samples is shown in Table 1.

In addition to these samples, additional samples may be required. These additional samples are taken when the maximum microbiological contaminent levels are exceeded. When this happens, samples must be collected from the same sampling point on two consecutive days. Additional check samples from this point may be required until the problem is cleared up.

The E.P.A. has also set up standards for the amount of coliform bacteria allowed in water. These maximum contaminant levels are exceeded, using the membrane filter technique, when one of the following occurs.

1. More than one colony per 100 ml for the average (arithmetic mean) of all samples examined per month.
2. More than four colonies per 100 ml in more than one sample, when less than 20 samples are examined per month.
3. More than four colonies per 100 ml in more than five percent of the samples, when more than 20 samples are examined per month.

TABLE 1

Population served:	*Minimum number of samples per month*
25 to 1,000	1
1,001 to 2,500	2
2,501 to 3,300	3
3,301 to 4,100	4
4,101 to 4,900	5
4,901 to 5,800	6
5,801 to 6,700	7
6,701 to 7,600	8
7,601 to 8,500	9
8,501 to 9,400	10
9,401 to 10,300	11
10,301 to 11,100	12
11,101 to 12,000	13
12,001 to 12,900	14
12,901 to 13,700	15
13,701 to 14,600	16
14,601 to 15,500	17
15,501 to 16,300	18
16,301 to 17,200	19
17,201 to 18,100	20
18,101 to 18,900	21
18,901 to 19 800	22
19,801 to 20,700	23
20,701 to 21,500	24
21,501 to 22,300	25
22,301 to 23,200	26
23.201 to 24,000	27
24,001 to 24,900	28
24,901 to 25,000	29
25,001 to 28,000	30
28,001 to 33,000	35
33,001 to 37,000	40
37,001 to 41,000	45
41,001 to 46,000	50
46.001 to 50,000	55
50,001 to 54,000	60
54,001 to 59,000	65
59,001 to 64,000	70
64,001 to 70,000	75
70,001 to 76,000	80
76,001 to 83,000	85
83,001 to 90,000	90
90,001 to 96,000	95
96,001 to 111,000	100
111,001 to 130,000	110
130,001 to 160,000	120
160,001 to 190,000	130
190,001 to 220,000	140
220,001 to 250,000	150
250,001 to 290,000	160
290,001 to 320,000	170
320,001 to 360,000	180
360,001 to 410,000	190
410,001 to 450,000	200
450,001 to 500,000	210
500,001 to 550,000	220
550,001 to 600,000	230
600.001 to 660,000	240
660,001 to 720,000	250
720,001 to 780,000	260
780,001 to 840,000	270
840,001 to 910,000	280
910,001 to 970,000	290
970,001 to 1,050,000	300
1,050,001 to 1,140,000	310
1,140,001 to 1,230,000	320
1,230,001 to 1,320,000	330
1,320,001 to 1,420,000	340
1,420,001 to 1,520,000	350
1,520,001 to 1,630,000	360
1,630,001 to 1,730,000	370
1,730,001 to 1,850,000	380
1,850,001 to 1,970,000	390
1,970,001 to 2,060,000	400
2,060,001 to 2,270,000	410
2,270,001 to 2,510,000	420
2,510,001 to 2,750,000	430
2,750,001 to 3,020,000	440
3,020,001 to 3,320,000	450
3,320,001 to 3,620,000	460
3,620,001 tc 3,960,000	470
3,960,001 to 4,310,000	480
4,310,001 to 4,690,000	490
4,690,001 or more	500

Minimum number of samples required by Safe Drinking Water Act (PL 93-523) for bacteriological testing.

When using the fermentation tube method with 10 ml portions, the maximum contaminant levels are exceeded when one of the following occurs.

1. More than 10 percent of the portions in any month has coliform bacteria present.
2. Three or more portions in more than one sample has coliform bacteria present, when less than 20 samples are examined per month.
3. Three or more portions in more than five percent of the samples has coliform bacteria present, when 20 or more samples are examined per month.

If these standards are exceeded, the EPA must be notified in seven days and the consumer by mail within three months or on the first water bill, whichever comes first. The newspaper must be notified so that publication in the paper for three consecutive days will occur within 14 days and the radio and television stations in the area must be notified within 7 days. Customer and state notification, as stated above, is required not only for exceeding maximum contaminant levels for bacteria but also for organic and inorganic contaminants. (These contaminants and their maximum contaminant levels are given in Module 2, on Basic Chemistry.)

MISSOURI WATER QUALITY STANDARDS

In Missouri, the Department of Natural Resources is responsible for the quality of drinking water in the state. This agency makes and enforces the regulations concerning the sampling, collection and maintenance of water supplied to the public. They approve all water supplies as well as any new waterworks systems.

This Department follows the regulations set for by the E.P.A. as given in the last section. In addition, the Department requires that no less than four samples of water for bacteriological examination each month and one for chemical analysis each year be taken for non-treated supplies. For treated supplies, no less than four water samples per week for bacteriological examination and one water sample per year for chemical analysis be taken. These samples are to be sent to the laboratories of the Division of Health. This Division will furnish the containers to take the required samples along with instructions. These instructions are reprinted on the following page with permission of the Department of Natural Resources.

STATE OF MISSOURI

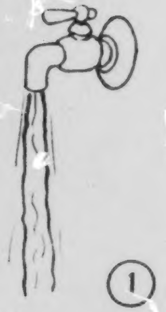
Department of Natural Resources
DIVISION OF ENVIRONMENTAL QUALITY
Water Supply Program

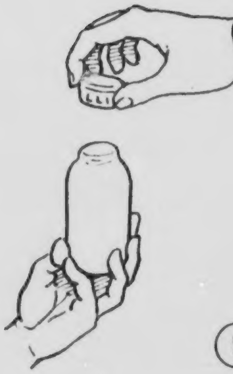
Department of Social Services
DIVISION OF HEALTH
Section of Laboratory Services

See reverse side

METHOD FOR COLLECTING WATER SAMPLES FOR BACTERIOLOGICAL ANALYSIS

"FOR POTABLE (Drinking) WATER ONLY"
Do not use for sampling ponds, streams
or other surface waters.

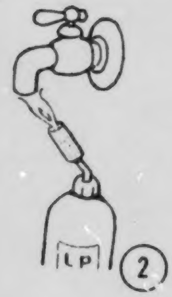

①


⑤

Only samples collected in our bottles, in accordance with these instructions, will be accepted for analysis.

Do not open bottle until all instructions have been read.

The sample should be taken from a smooth-nosed cold water tap if possible. Avoid collecting sample from a frost-proof hydrant (8) or from hot-cold mixing faucets (9), since it is not practical to sterilize these fixtures. Ship the sample **IMMEDIATELY** after collection. This is important because water samples should be in transit no more than 30 hours if bacteriological findings are to be accurate.



②

(1) Allow the water to run full open approximately 1 minute or until the service line has been thoroughly flushed.

(2) Flame-sterilize the tap from its nose to the valve, being certain that the open end has been well heated.

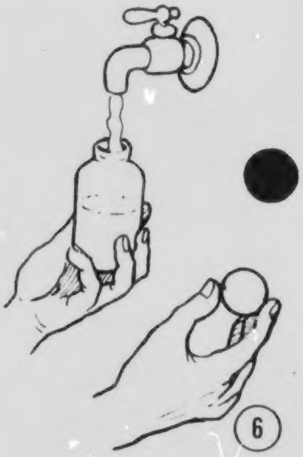
(3) Turn on the water and adjust the stream to a gentle flow. Do not rinse the container.

(4) The sample containers are sterile and ready for use when shipped. DO NOT RINSE THE CONTAINER. A LOOSE CAP DOES NOT AFFECT STERILITY.

(5) Grasp cap along top edge and remove. Do not touch inside of cap or neck of bottle and do not attempt to clean or rinse the bottle.

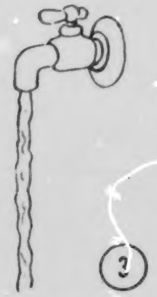
(6) Hold bottle so that water entering it will not pass over your hands. Allow water to flow smoothly from pump or tap and fill the bottle to about ½ inch of top (or to the black line on some bottles.)

(7) Replace cap on bottle and tighten cap securely.


⑥

SHIPPING INSTRUCTIONS

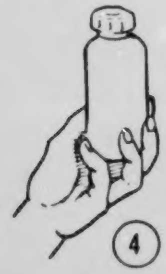
Due to the laboratory's mailing schedules, a water supply may receive their bottles at the end of the week. Collect samples only on Monday, Tuesday, or Wednesday, except in emergency. Samples should not be enroute to the laboratory over the weekend or a state holiday.


③

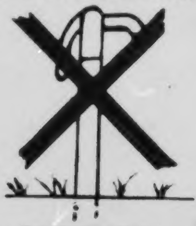
Collect samples only a short time before shipping. Samples must be tested within 30 hours after collection. Check with your local postmaster for time of dispatch and collect the samples in time to be included in the shipment to Jefferson City or to the branch laboratories. USE FIRST CLASS POSTAGE TO INSURE TOP FORWARDING PRIORITY.

INFORMATION CARD: Fill out a separate card for each water sample submitted. Supply all information requested on the card and enclose card with the sample container. Be certain that number on card matches number on bottle.

Bottle is clean and sterile
Ready for sample
(A loose cap does not affect sterility)

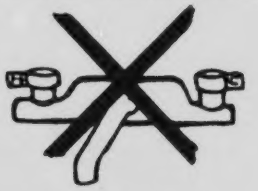

④

FROST-PROOF HYDRANT

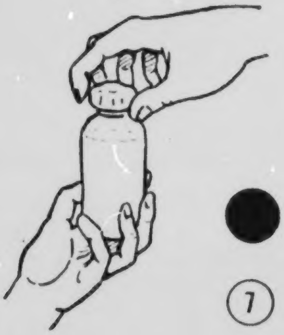


DO NOT USE ⑧

HOT-COLD MIXING FAUCET



DO NOT USE ⑨


⑦

The form that should accompany each bacteriological sample to the Division of Health is illustrated in Figure 3 along with an explanation of how to fill it out. Note that when the form is returned by the State, space number 17 will contain the results of the tests.

If samples are examined for bacteria in your laboratory, the sampling method described by the Department of Natural Resources should be followed. "Standard Methods," 14th Edition procedures must be followed for bacteriological testing. The sampling bottles used should be of suitable size. These should have been washed and rinsed with great care using distilled water after which a dechlorinating agent such as sodium thiosulfate should be added. The containers are then sterilized in a hot air oven for not less than 60 minutes at 170 degrees Centigrade or in an autoclave for 15 minutes at 121 degrees Centigrade.

22

Lab. 10D Rev. 4/78

BACTERIOLOGICAL WATER ANALYSIS

WEEKLY

Department of Social Services
MISSOURI DIVISION OF HEALTH
Section of Laboratories

Public Water System Name and Address

Bottle No. 3

Is Supply Chlorinated? Yes ☐ No ☐

6

1
SUPPLY NAME
2
STREET ADDRESS
3
CITY ZIP
4
COUNTY

Laboratories	(✓)	Lab ID (42-46)
Jefferson City	☐	0 0 0 0 3
7 Poplar Bluff	☐	0 0 0 0 4
Springfield	☐	0 0 0 0 5

Sample Type Key (37)
D distribution sample
P plant or well tap sample
C check sample
R raw water
S special sample

Location Code (28-30)	Point of Sample Location (30A)	Sample Date MO (31)	Sample Date DAY	Sample Date YR (36)	Sample TYPE (37)	Sample TIME (38-41)	Collected By	Analyzed By
8	9		10		11	12	13	14

PWS ID (1-7)	See Reverse Side for Instructions (8-16)	Serial No. / RESULT (17-20)	Decimal (21)	Analysis Date MO (22)	Analysis Date DAY	Analysis Date YR (27)
15	05 3 000 3 03	Serial No. 16 RESULT 17 Coliforms/100ml	0		18	

Please read and follow instructions

Lab ID (42-46)
Place a check (✓) after the laboratory name to which you are mailing the water sample (check return address label).

Location Code (28-30)
Used only for check samples; water superintendent will be instructed as to what number to use at that time.

Point of Sample Location (30A)
Give address or name of sample collection point.

Sample Date (31-36)
Use 2 digits for month, day and year. Example: Jan. 1, 1978 would be written as 01 01 78.

Sample Type (37)
Write letter to coincide with type of sample taken—see front for Sample Type key.

Sample Time (38-41)
Use 24 hr. clock in recording the time the sample was taken. Example: Sample taken at 2:30 p.m. would be entered as "1430" or 2:30 plus 12 hrs. = 1430 hours.

PWS ID (1-7)
Your 7-digit identification number *must* be entered for processing purposes. It may be found on the address label.

EXPLANATION OF BACTERIOLOGICAL WATER ANALYSIS FORM

1. State supply name as we know it, not as it is known locally.
2. Record the street address of the supply.
3. Record the name of the city in which supply is located as well as the zip code.
4. Record county in which water supply is located. This is important as we often have to notify County Health Department.
5. This is for bottle number which the Lab has written on the side of the bottle, usually with an indelible pen.
6. Simply put a check in the appropriate box.
7. Place a check after the laboratory name to which you are mailing the water samples.
8. Used only for check samples. Water superintendent will be instructed as to what number to use at the time.
9. Record the name of the resident of the house or name of the business and its street address.
10. Time is an important element in the bacteriological process because the results may be erroneous after a sample has aged for more than 30 hours. Please take care to write correct date.
11. Select appropriate letter from Sample Type Key and write it in "Type" column.
12. As stated above, we measure the age of the sample by hours, not days; therefore, we must know the time of the collection. Do not collect samples just prior to a weekend or holiday. Check the time of mail departure from your local post office.
13. This should be the name of the person actually collecting the sample. If the sample is "positive" or "bad", we will want to talk to the person making the collection in order to observe his procedure.

14, 16, 17 & 18. Please do not write in these areas as they are used by Lab Personnel.

15. Your 7-digit identification number must be entered for processing purposes. It may be found on the address label.

PLEASE TAKE CARE TO WRITE LEGIBLY!

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. *Basic Level Water Treatment Operator's Practices*, AWWA No. M18 Denver Co pp. 17-25.
2. *Manual of Instruction for Water Treatment Plant Operators*, New York State Department of Health, Office of Public Health Education, Albany, NY pp. 75-96.
3. *Opflow*, AWWA, Vol. 4, No. 7, July 1978.
4. *Standard Methods for Examination of Water and Wastewater*, 13th Edition, 1971, 874 pages.
5. *Safe Drinking Water Act*, Information about this act can be obtained by writing to:

   United States Environmental Protection Agency
   1735 Baltimore
   Kansas City, MO 64108

   or

   AWWA
   6666 W. Quincy Ave.
   Denver, Co 80235

6. Missouri Standards can be obtained by writing to:

   Department of Natural Resources
   Division of Environmental Quality
   P.O. Box 1368
   Jefferson City, MO 65101

POST-EVALUATION (5 pts. each)

1. True or False
   a. Bacteria are microscopic one-cell organisms.
   b. A person can contact a disease by drinking polluted water.
   c. When collecting a water sample for bacteriological testing, it is not necessary to flame the tap or flush out the line.
   d. Water may be clear and sparkling and still contain disease-bearing bacteria.
   e. All bacteria are extremely small, but a few varieties can be seen with the naked eye.
   f. All coliform organisms are capable of causing disease.
   g. Bacteriological tests are conducted to determine the number of coliform bacteria because these are the most deadly to man.
   h. The presence of algae in water causes the disease known as algicide.

2. Match the correct term on the left with the one on the right.
   a. Bacilli
   b. Cocci
   c. Spirilla
   d. Cause of cholera
   e. Cause of hepatitis
   f. Fungi
   g. Protozoa

   1. have characteristics of plants and animals
   2. Rod-shaped bacteria
   3. Bacteria
   4. Yeast and molds
   5. Curved-shaped bacteria
   6. Viruses
   7. Round-shaped bacteria

3. Bacteria found in water may be classified as follows:
   a. Pathogens
   b. Non-pathogens
   c. Both of the above
   d. None of the above

4. Three waterborne diseases are:
   a. mumps, measles, colds
   b. scarlet fever, pneumonia, hay fever
   c. typhoid fever, dysentery, cholera
   d. TB, diptheria, chickenpox

5. Which one of the following diseases may be waterborne?
   a. Paratyphoid fever
   b. Malaria
   c. Tuberculosis

6. Algae can cause:
   a. taste problems
   b. odor problems
   c. turbidity
   d. all of the above
   e. none of the above

7. A bloom is caused by:
   a. bacteria
   b. viruses
   c. algae
   d. fungi
   e. Protozoa

ANSWERS

1. a. T
   b. T
   c. F
   d. T
   e. F
   f. F
   g. F
   h. F

2. a. 2
   b. 7
   c. 5
   d. 3
   e. 6
   f. 4
   g. 1

3. c

4. c

5. a

6. d

7. c

MODULE 5

SELF-INSTRUCTIONAL

Paul Hummel - NMSU

BASIC ELECTRICITY

PREREQUISITES: Module One - Basic Mathematics

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION (10 points each)

1. A circuit containing 100 Ω resistance and having 4.8 A of current is impressed with how many volts?
2. A 24 watt car bulb is run from a 6 volt battery. How many amperes of current does it draw?
3. Convert 5 horsepower to kilowatts.
4. Match Column B with column A.

Column A

1. _____ volt
2. _____ A.C.
3. _____ static electricity
4. _____ fuse
5. _____ D.C.
6. _____ 1 m A
7. _____ Dynamic electricity

Column B

A. short metal ribbon with a low melting point
B. 1000 μ A
C. electricity created by a battery or a generator
D. electrical current flowing in one direction
E. unit of pressure
F. transformer
G. standardized in U.S. at 60 cycles per second
H. 1000 A
I. rectifier
J. electrical charge caused by friction
K. unit of resistance

ANSWERS

1. 480 volts
2. 4 amperes
3. 3.73 kilowatts
4. 1) E
   2) G
   3) J
   4) A
   5) D
   6) B
   7) C

INTRODUCTION

You will encounter electrical terms and problems everyday in your job. This module is designed to give you basic knowledge of what electricity is and how it works.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the following concepts;

1. Basic electrical terms
2. Kinds and types of electricity
3. Circuits

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

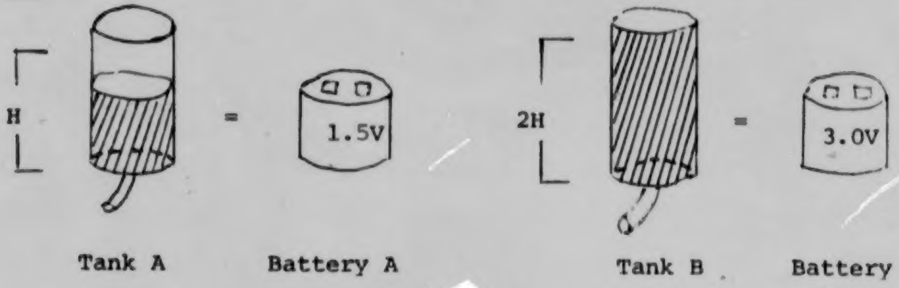
Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

BASIC ELECTRICITY

In order to understand what electricity is, one must be acquainted with the language used in this subject. Some of the basic terms of this subject are listed below with their definitions.

1. E.M.F. or Electromotive Force: This term describes the push that gets the electric current flowing. This push or force is measured in volts.
2. VOLT (v): Electricity if very much like water. For example, water exerts a pressure on the material it is passing through. Electricity also exerts a pressure on the material that is conducting it. This pressure is measured in voltage (symbolized v). If one raises the voltage passing through a conductor, one increases the electricial pressure. This is like imagining two tanks, A and B. Tank A is .7 full; Tank B is twice as full. A pipe leads from the bottom of each tank. The pressure from Tank B created by the water flowing through the pipe is twice as great as Tank A. Similiarly a battery (B) with twice the voltage of another (A) will exert twice as much pressure as the second. (See Figure 1)

FIGURE 1



Voltage = [illegible]essure

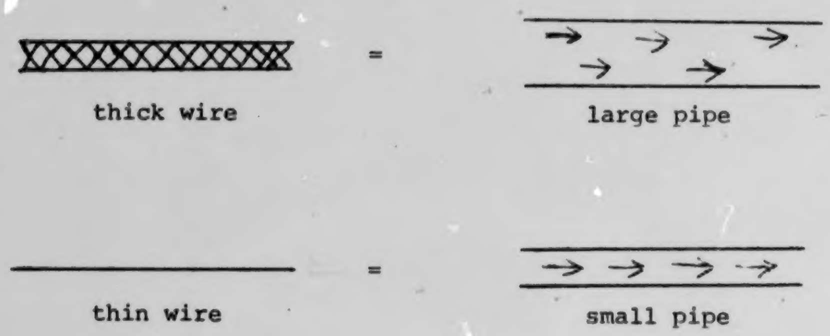
Some equipment operates at high voltage. This is measured in kilovolts (kV). 1000 volts = 1 kilovolt. Other equipment operates at very low voltage which is measured in millivolts (mV). 1000 millivolts = 1 volt. Extremely low voltages are measured in microvolts (μV). 1000 microvolts = 1 millivolt.

3. Ampere (A): The amount of electricity which flows past a point in a certain amount of time is called amperes or amps. It is a measure of the current symbolized by A. Small currents are given in milliamperes or mA. 1000 mA = 1 ampere. Extremely small currents are in microamperes or μA. 1000 μA = 1 milliampere.

4. Ohms Ω : The ohm symbolized by the Greek letter omega Ω is the unit of resistance. Like water flowing through a large pipe, electricity flowing through a thick wire encounters little resistance to slow it down. A thin wire resists the ready flow of electrical current, just as a small pipe offers resistance to the flow of water. Therefore, the greater the resistance or ohms present in a circuit or wire, the more the passage of current is hindered. (See Figure 2) Some substances, such as copper wire, offer little resistance, so they let current pass readily. Others, such as glass, carbon and rubber resist the ready flow of current. These materials, therefore, are used as insulators. That is, they contain the electricity to the conductor, such as copper wire.

For high values of resistance we use kΩ or kilo-ohms.
1 kΩ = 1000 . Very high values are in MΩ (megohms).
1 MΩ = 1000 k .

FIGURE 2



5. **Ohm's Law**: Ohm's Law states the relationship between voltage, amperage and resistance. If we increase the voltage applied to a circuit, the current becomes stronger. Reducing the voltage makes the current weaker. If the voltage is left the same but the resistance is increased, the current becomes weaker. Reducing the resistance allows more current to flow. These facts are the basis of Ohm's Law. We say current (A) is equal to the pressure (V) divided by the resistance (Ω) or $A = \frac{V}{\Omega}$. We can also say $A \times \Omega = V$. For example: If 1 mA encounters resistance of 100 kΩ, what is the voltage dropped? If 1 mA = 0.0001 ampere and 100 kΩ = 100,000 ohms, then:

$$\begin{aligned} V &= A \times \Omega \\ &= 0.001 \times 100{,}000 \\ &= 100 \text{ volts} \end{aligned}$$

100 volts are dropped.

6. **Watt (W)**: The power that is usefully employed or wasted in a circuit is called watts (W). Small powers are given in milliwatts. (mW) 1000 milliwatts = 1 watt. This power that is present in a circuit is equal to the pressure or voltage (V) times the current or amperage (A). $W = V \times A$. For example, the wattage of a bulb run by a 12 volt battery by a current of 3 amperes is 36 watts.

$$\begin{aligned} W &= V \times A \\ W &= 12 \times 3 \\ W &= 36 \text{ watts} \end{aligned}$$

Like watts which measures the power found in a circuit at any given moment; horsepower measures the total power produced by a motor at any given moment. One horsepower equals 746 watts or 0.746 kilowatts.

SELF-TEST

1. __________ is the term used to describe the pressure electricity creates.	volts
2. __________ is the term used to describe electrical flow.	ampere
3. __________ is the term used to measure resistance.	Ohms
4. __________ __________ states the relationship between voltage, amperage, and resistance.	Ohm's Law
5. How many amperes flow through a circuit leading from a 12 volt battery to a 15 watt bulb?	
a. The formula for finding watts if the voltage and amperes are known is ________.	W = V x A
b. Substituting what is known in the equation, the equation now looks like ________.	15 = 12 x A
c. Solving for A, the answer is ________.	1.25 amperes

KINDS OF ELECTRICITY AND TYPES OF CURRENT

The above section contains some of the basic terms used in describing the different aspects of electrical energy. Let us now turn our attention to the kinds of electricity and the types of current.

Kinds of Electricity

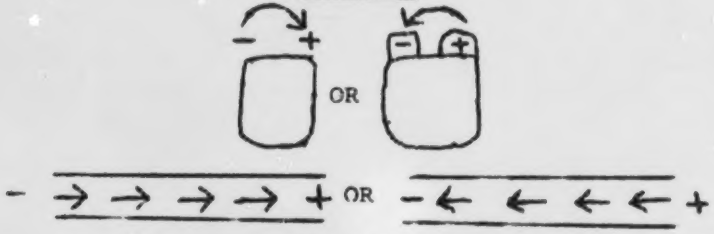
There are two main forms of electricity. One is static electricity and the other is dynamic electricity. Static electricity is a build up of an electrical charge caused by friction. This kind is easily demonstrated when one walks across a rug in socks on a cold day. As one reaches the other side of the room and touches a metal object, the built up charge is released when a spark jumps from your hand to the metal object. This is static electricity. In the water plant, static electricity can build up in rotating machinery or conveyor belts. This type of electricity is potentially dangerous because it may make a person jump causing an accident. It can also start fires or cause explosions. It can be prevented by providing a proper electrical connection to ground and earth.

Dynamic electricity is electricity in motion. It is created by a battery or dynamo. There are two types of motion. In one type, the electrical flow is from source to another point. In the other type, the flow goes in one direction and then returns in the opposite direction.

Types of Current

As we said in the above paragraph, there are two types of dynamic electricity. In one, the current goes in one direction. This type of current is called D.C. or Direct Current. Here, the current is either positively or negatively charged. In other words, the current will always flow from the negative connection of the source to a positive point at the receiving end or visa versa. (See Figure 3) Direct current can be developed by D.C. generators (rotating type) and can be obtained, as well as stored in, batteries.

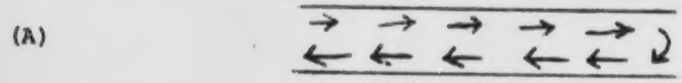
FIGURE 3



D.C. Current

The other type of dynamic electricity is called Alternating Current or A.C. In this type of electricity, the current flows first in one direction then another. The distance the current travels from the time it changes direction twice is called one cycle. One cycle is shown in Figure 4. The number of cycles per second is called the frequency. In the U.S. the frequency of 60 cycles per second is standard. In other words, AC current in the U.S. reverses direction of flow 120 times per second (twice per cycle). Alternating Current is generated by AC generators (rotating type.)

FIGURE 4



one cycle of A.C. current

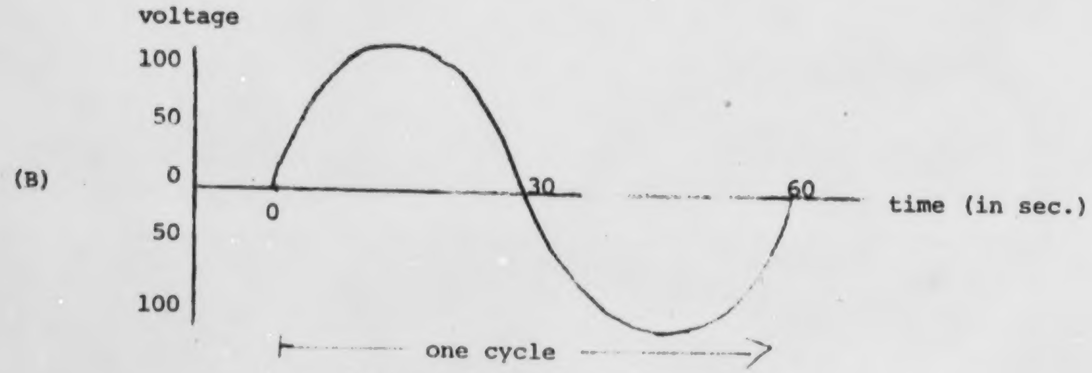
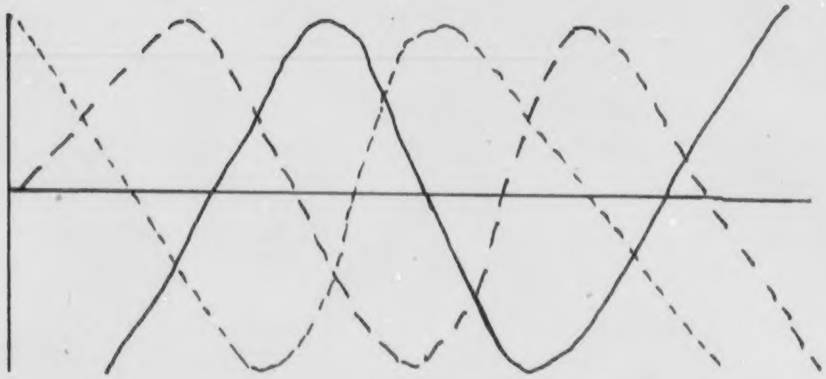


Figure B shows what happens if one could measure the voltage in one cycle. Here the voltage gradually increases as the current nears. When it changes direction the voltage drops until it reverses direction again, then the voltage increases. The time between when the voltage reads zero to the second time it reads zero is one cycle.

Three-phase current is nothing more than three separate A.C. waves on independent conductors. These are arranged so that, at any instant, if the voltage is at a particular phase in one conductor it is one-third wavelength ahead in another and one-third wavelength behind the third conductor (See Figure 5). Most large motors are three-phase, 60 cycle per second motors.

FIGURE 5



Three - Phase Current

SELF-TEST

1. The two types of electricity are __________ and __________.	Static and dynamic
2. D.C. means __________ __________.	Direct Current
3. In D.C. the current flows in how many directions?	One
4. In A.C. the current flows in how many directions?	Two
5. Three phase current is __________ __________ AC waves on independent conductors.	Three separate

CONTROL OF ELECTRICITY

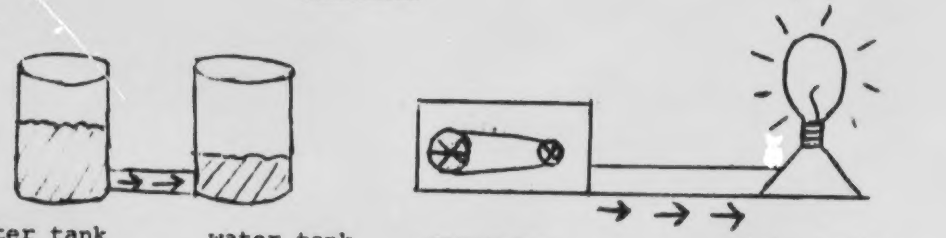
Like in a water distribution system where there are various valves and pumps which control the direction and power (pressure) of the water flowing through it, there are various devices which control the direction and power of electric current. These devices are discussed in the following section.

A. Electric Circuits

As we have pointed out before, electricity is very similiar to water in many ways. Another similiarity is seen in the way electricity flows. As water flows from a container with higher pressure to one of lower pressure, so will electricity flow from any point of higher voltage (pressure) to a point of low voltage if there is an electric connection (See Figure 6).

An electric circuit consists of a power source such as a battery or generator, that which is powered by electricity such as a light bulb or motor (this is called a load) and a means of transporting the electricity from the source to the load and back to the source such as copper wire (called a conductor). If all three elements are present then one has a complete circuit. (See Figure 7). The circuit can be thought of as a pump (power source) forcing the flow (current) through a pipe (conductor) and back through the pump. Any apparatus (load) on this loop (circuit), which is driven by the water (current), adds resistance to the flow. A closed valve in the water line stops the current of water like an open wire or switch in an electric circuit stops the flow or current of electricity.

FIGURE 6

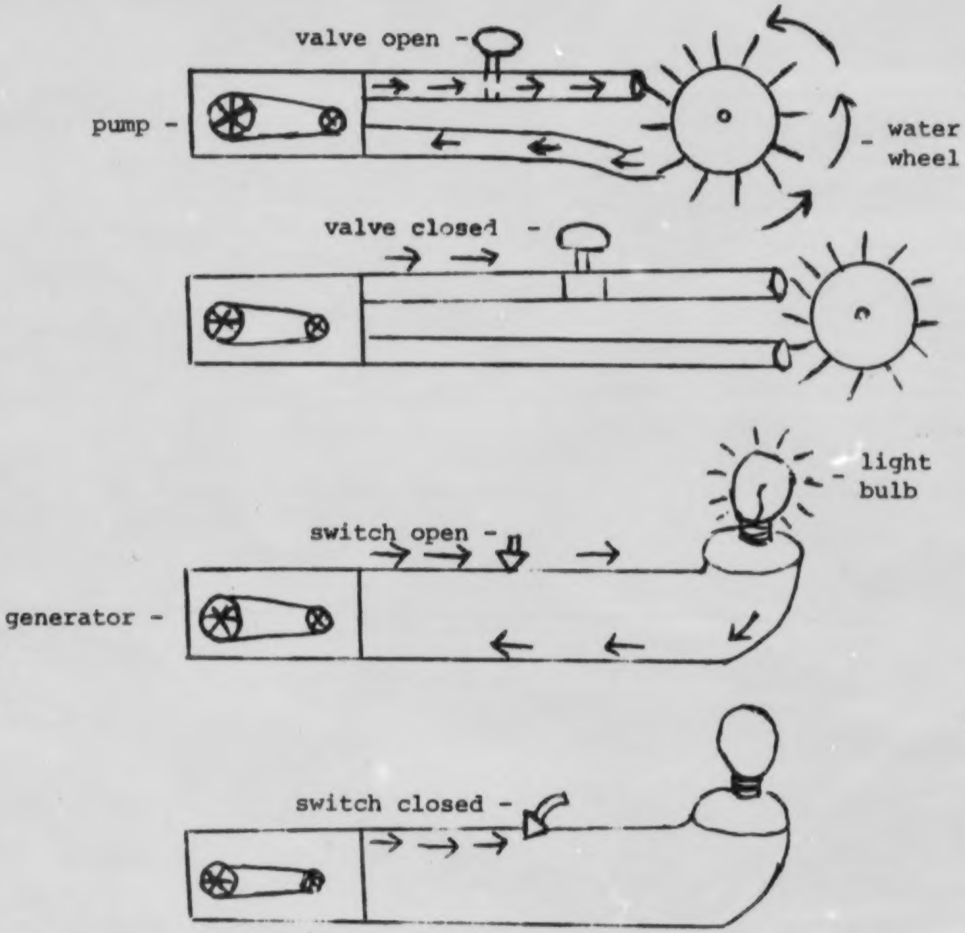


water tank with high pressure TO water tank with low pressure

generator with high electrical pressure TO light bulb with little electrical pressure

Electrical Flow

FIGURE 7

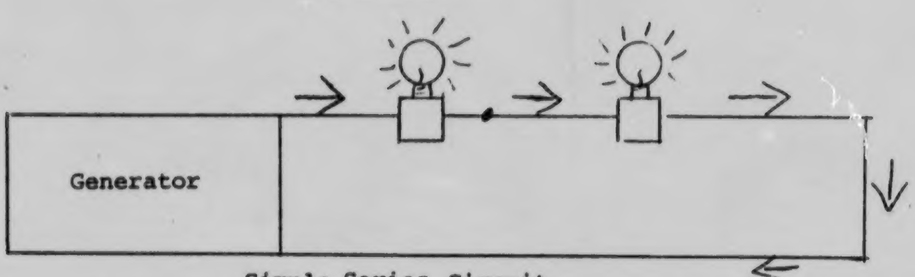

valve open -
pump -
water wheel
valve closed -
light bulb
switch open -
generator -
switch closed -

Water and Electrical Circuits

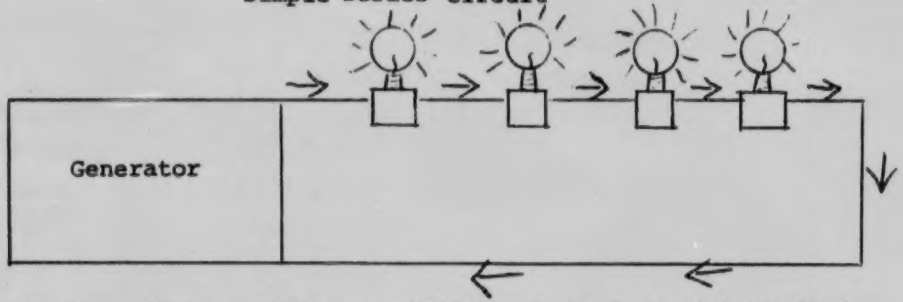
B. Types of Circuits

There are three types of circuits. In the series circuit all resistances or loads are in a series. Here, the electrical current is the same strength in all the paths it can take no matter how many paths or circuits there are. In this type of circuit, the more resistance units or loads we place on the system, the smaller the current becomes. This decrease in current is the same on all parts of the circuit. (See Figure 8). If the current is cut off in any part of the circuit, the entire circuit looses current because the circuit is not complete.

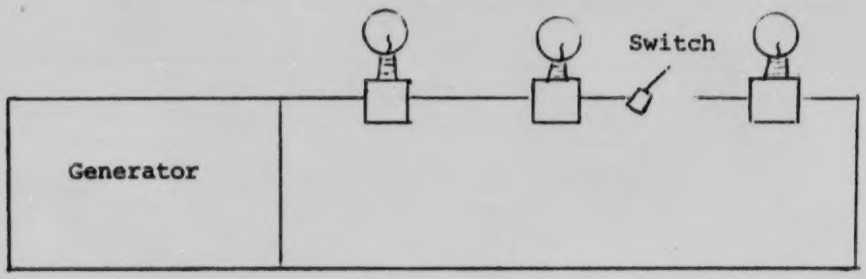
FIGURE 8



Simple Series Circuit



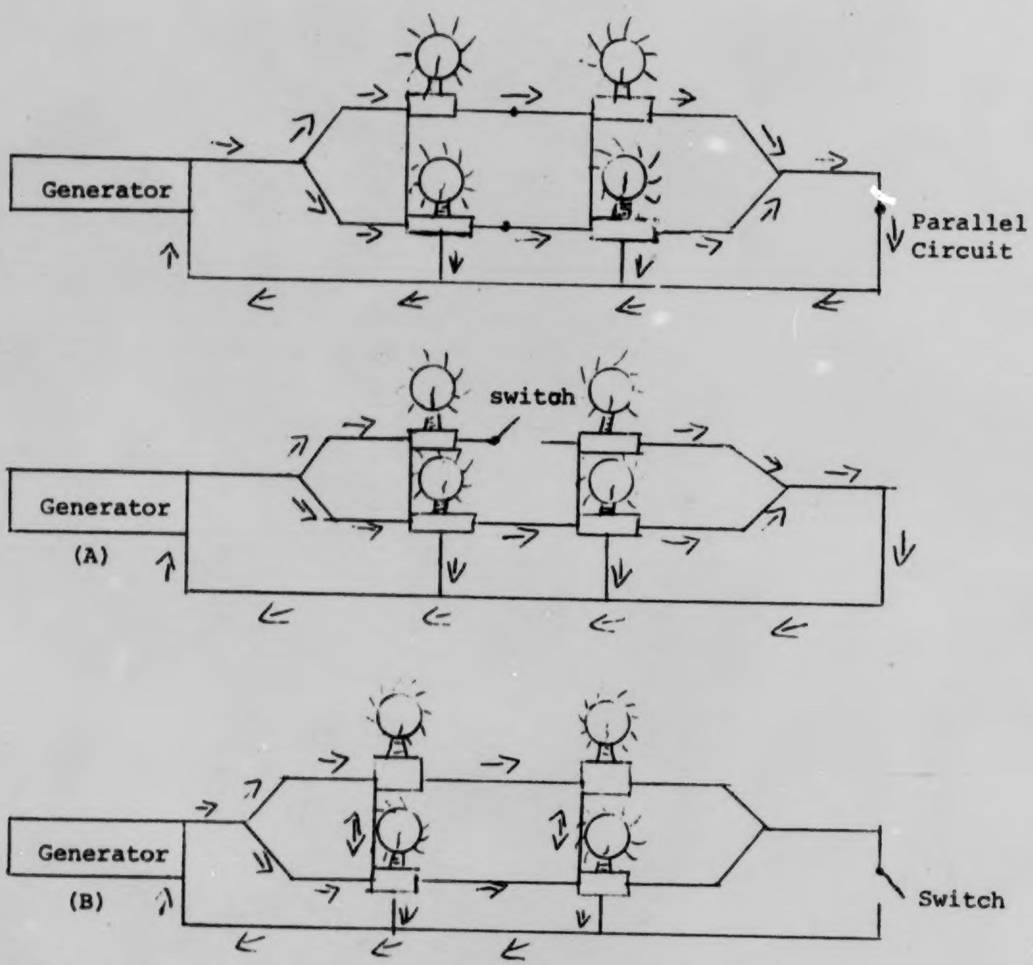
Decrease in Current due to additional load (2 light bulbs)



No current flow because the circuit is broken by the switch

The second type of circuit is the parallel circuit. In this type of circuit, the loads are connected to each other in such a way that they have more than one way of receiving electricity. In other words, the electric current can take alternate routes to the various loads. Every conductor or load added in parallel effectively increases the size of the conductor, so that the resistance is decreased and the flow increased. The advantage to this type of circuit is that if the flow is cut off to one load, the flow continues through the parallel routes. Each parallel route is subject to the same pressure or voltage. (See Figure 9).

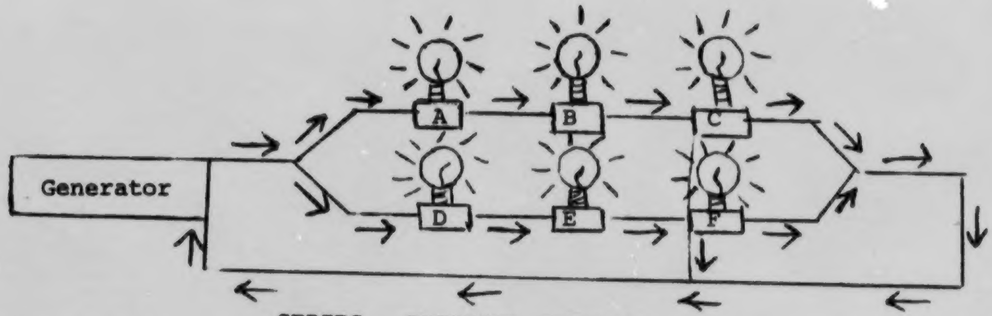
FIGURE 9


Generator
Parallel
Circuit
switch
Generator
(A)
Generator
(B)
Switch

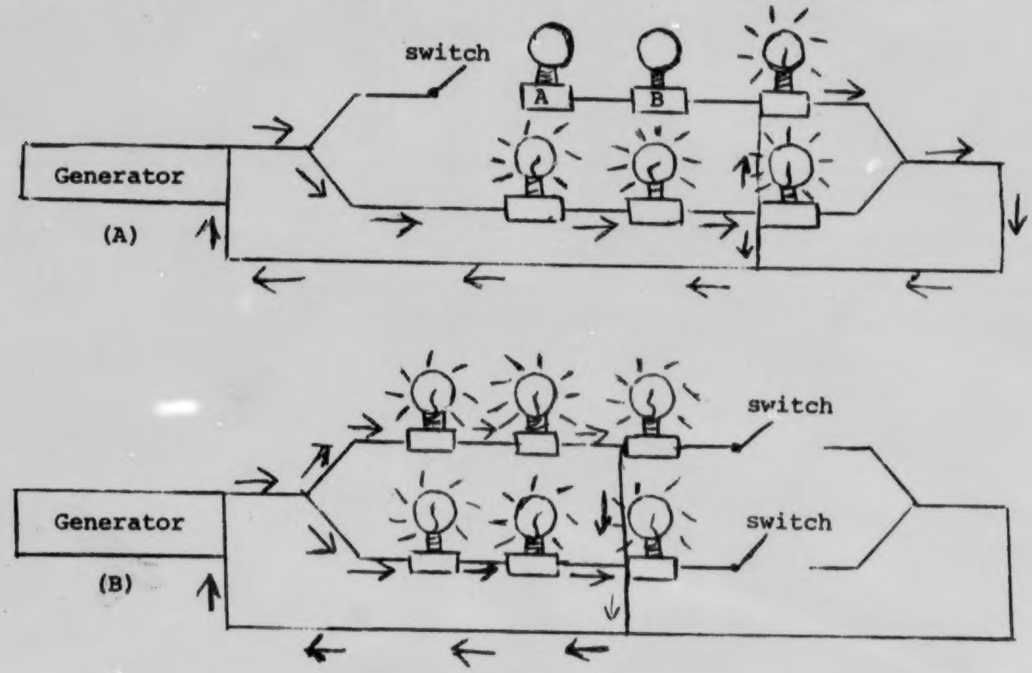
Figures A and B show what happens when a switch is opened in the parallel circuit.

The series-parallel circuit is the third type of circuit and is a combination of the parallel circuit and the series circuit. The rules governing parallel circuits apply to the parallel part of the circuit and the rules governing series circuits apply to the series part of the circuit. (See Figure 10) of the three types of circuits, the most commonly encountered is the parallel circuit.

FIGURE 10


Generator
A
B
C
D
E
F

SERIES - PARALLEL CIRCUIT
(with bulbs A, B, D, E in SERIES and bulbs C, F in PARALLEL CIRCUIT)


switch
A
B
Generator
(A)
switch
switch
Generator
(B)

Figures A and B show what happens when various switches are opened in the SERIES - PARALLEL CIRCUIT.

These circuits are often grounded. This means that one end of the electrical circuit is connected to the earth or a large conductor that is connected to the earth. Motor frames and all electrical equipment should be grounded. This will prevent a voltage charge from accumulating on the surface or within mechanical parts of any equipment.

The third prong on cords from electrical equipment is the connection to the ground and should never be cut off. If this equipment is to be used with an adaptor, the green wire on the adaptor should be connected to the center screw on the receptacle cover plate. Often electrical equipment is grounded by attaching the grounding wire to water pipes. This is a dangerous practice because of the use of nonconductor materials in these pipes. In other words, the equipment will not be properly grounded because there is no connection between the equipment and earth where excess electricity can travel.

Improper grounding may result in a person receiving a shock or being electrocuted. This is because the normal resistance of the wiring is bypassed, causing an electrical charge to build up. When a person touches the equipment or a live circuit, he becomes the ground. Thus his body acts as a conductor causing electricity to flow through his body.

C. Electrical Protection

There are times when the demand of the equipment increases the amperage flowing through a circuit. This increase in amperage may damage some of the equipment not built to withstand high amperage for any period of time. In order to prevent an overload, we use devices such as fuses, circuit breakers and thermal relays.

A fuse is a short piece of wire or metal ribbon with a low melting point. At normal current demands, the fuse carries the current with no problem. If there is a high amperage demand, the fuse melts breaking the circuit.

Circuit breakers are operated by heat or electromagnetism. They are switches that break the circuit when there is an overload.

Motors are often protected by thermal relays. These sense temperature changes so that when current demands heat up the conductor, a relay trips, cutting off the current flow to the motor.

In order to insure that more current than the equipment can handle is not being received by the equipment, make sure to use the proper size and type of wire for that equipment. It may also be necessary to place the wire in conduit pipe to prevent physical damage or damage from moisture. Plastic conduit pipe should have an extra wire inside to connect all exposed metal parts to ground.

The ground wire from equipment is normally green. The neutral wire to electrical equipment should also be grounded. It is normally white.

SELF-TEST

1. The components of a circuit are the _______, _______, and _______.

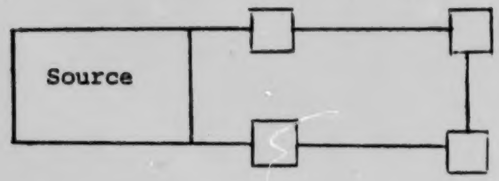
conductor, load, source

2. What are the three types of circuits?

Series, Parallel and Series-Parallel

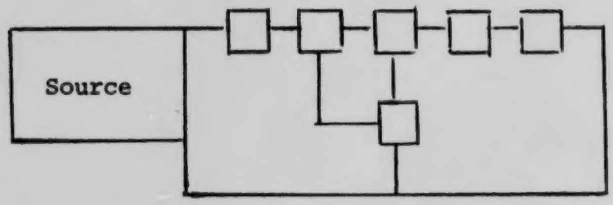
3. Name the following circuits:

a.



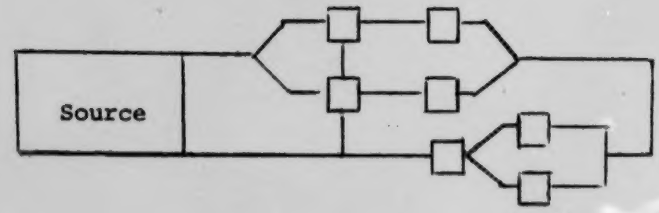
Series

b.



Series - Parallel

c.



Parallel

4. A short piece of wire or metal ribbon with a low melting point used to protect electrical circuits is called a _________.

fuse

FURTHER ELECTRICAL TERMS

1. Capacitor: a device to store electrical energy until needed.
2. Coils (Inductor): a device to keep the current constant.
3. Impedance: a from of resistance. This is caused by a flow of electricity going against the main current. This counter current in effect slows down the main flow of electricity.
4. Inductance: to keep the electric current constant.
5. Rectifier: device allowing current to pass easily in one direction only.
6. Resistance: hinderance of electricity caused by friction (measured in Ohms).
7. Transformers: device to step up or step down voltage.

SUGGESTED READINGS

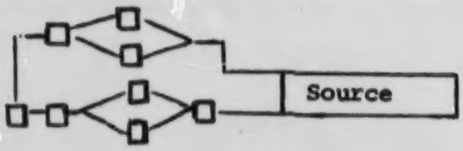
If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book

1. Electronics, by Roland Worcester, 1971, Bantam Books, New York, N.Y.
2. Manual of Instruction for Water Treatment Plant Operations, New York State Department of Health, Office of Public Health Education, Albany, New York pp. 39-44.
3. Water Distribution Operator Training Handbook, American Water Works Assn., pp. xii-1 to xii-8.

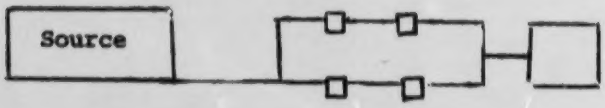
POST-EVALUATION (10 points each)

1. Name the following circuits:

a.



b.



2. Convert 10 HP to kilowatts

3. Matching

a) ____ Ohms	A. states relationship between voltage amperage and resistance
b) ____ Parallel Circuit	B. measure of current
c) ____ Ampere	C. connected to the earth
d) ____ Ohm's Law	D. ∿
e) ____ Volts	E. states relationship between Ohms and volts
f) ____ Series circuit	F. measure of pressure
g) ____ Grounded	G. the loads are connected to each other such that they have more than one way of receiving electricity
	H. if the current is cut off in any part of the circuit, the entire circuit looses power.

ANSWERS

1. a) Series-parallel circuit
   b) Series circuit

2. 7.46 kilowatts

3. a) D
   b) G
   c) B
   d) A
   e) F
   f) H
   g) C

MODULE 6

SELF-INSTRUCTIONAL
Paul Hummel - NMSU

HYDRAULICS

PREREQUISITES: Module One - Basic Mathematics

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION (20 pts. each)

1. What force would act to blow a cork out of a hole 0.6 square inches? This hole is adjacent to a gauge connection on the side of a standpipe. The gauge shows that there is a head of 89 ft. of water above the hole.
2. A vertical gate in the face of a dam is 3 feet wide and 8 ft. high. The gate is kept closed by the pressure of an 8 foot head. What is the total force which acts to keep the gate closed?
3. What is the total force acting on the side of a tank which is 10 ft. high and 5 ft. long?
4. A flow of one million gallons per day occurs in an eight-inch pipeline. What is the flow velocity?
5. What causes "Water Hammer"?

ANSWERS

1. 23.1 lbs.
2. 11,980.8
3. 15,600 lbs.
4. 4.43 fps.
5. It is caused by closing a valve or stopping a pump too quickly.

INTRODUCTION

The flow of water through pipes and channels and the effects of pressure exerted by water is the subject of this module. While the subject of hydraulics can be quite complex, this module only covers the basics. It's purpose is to give you some understanding of the forces you will be dealing with when you read a gauge on a water tank or lay a pipe.

PERFORMANCE OBJECTIVE

When this module is completed, you will be able to show that you have mastered the following concepts:

1. Force and Pressure
2. Velocity and Rate of Flow
3. Friction Loss and C Factors
4. The Effects of Pressure

Mastery of this module will be shown by answering of the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you can understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

PRESSURE

Imagine yourself stepping out of a small jon boat after a successful fishing trip. What happens to the boat as you step out? Normally it moves away from you. Why? Because you give it an unintentional shove with your foot as you step out. This shove forces the boat in the opposite direction from which you headed. The water in the water distribution system is moved in the same way as the boat is moved.

Water moves or flows because something causes it to move. This "something" is called force and when this force is applied to a certain area of water, it is called pressure. So, we can say pressure is the force per unit area.

The force which creates pressure can be caused by a number of things such as gravity or an operating pump. Gravity is the most important force acting on water that is not being moved by a pump. Gravity is what gives objects weight. It gives a gallon of water the weight of 8.34 lbs. Since gravity is considered a force and we measure gravity in terms of weight such as pounds, tons, grams or kilograms, force can be measured by pounds, tons, grams or kilograms.

Pressure is measured in force per unit area, such as pound per square inch. In hydraulics, this measurement is abbreviated psi or pounds per square inch.

An example should serve to illustrate how these measurements are made. If water were poured into a one foot cubical container, it would create a force on the bottom of the container. This force would be equal to 62.4 pounds since -

1. The volume of the cube is 1 cu. ft. - $V = l \times w \times h$
   $V = 1\text{ ft.} \times 1\text{ ft.} \times 1\text{ ft.}$
   $V = 1\text{ cu. ft.}$
2. 1 cu. ft. of water equals 7.48 gal.
3. 1 gal. equals 8.34 lbs.
4. Therefore: $1\ \cancel{\text{cu.}}\ \cancel{\text{ft.}} \times \frac{7.48\ \cancel{\text{gal.}}}{1\ \cancel{\text{cu.}}\ \cancel{\text{ft.}}} \times \frac{8.34\text{ lbs.}}{1\ \cancel{\text{gal.}}} = \text{wt. of water in 1 cu. ft.}$
   $7.48 \times 8.34\text{ lbs.} =$
   $62.4\text{ lbs.} =$

The force per unit area or pressure acting on the bottom would be 62.4 pounds per square foot (area of bottom). Another way of expressing the area of the bottom is in square inches. This area would be equal to 144 sq. inches since -

1. 1 ft. = 12 in.
2. Area = l x w
   = 12 in. x 12 in.
   = 144 sq. in.

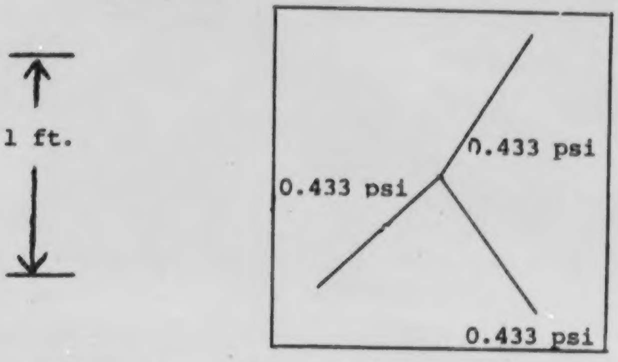
Therefore the pressure acting on the bottom may also be expressed as:

$$\text{Pressure} = \frac{62.4 \text{ lbs.}}{1 \text{ sq. ft.}} = \frac{62.4 \text{ lbs.}}{144 \text{ sq. in.}}$$

$$= 0.433 \text{ lbs./sq. in. or } 0.433 \text{ psi}$$

An important thing to remember here is that the water is exerting a pressure not only on the bottom of the container but also on the sides and top. Therefore the pressure in any vessel which has a depth of water of one foot is 0.433 psi acting in any direction.

FIGURE 1



If the depth of water were increased to 2 feet, the pressure would be:

$$p = \frac{2(62.4 \text{ lbs.})}{144 \text{ sq. in.}} = \frac{124.8 \text{ lbs.}}{144 \text{ sq. in.}} = 0.866 \text{ psi}$$

We can see, therefore, that for every foot the depth is increased, the pressure increases by 0.433 psi. The general formula for pressure is:

1. $P = 0.433 \times H$

P = pounds per square inch of pressure

H = height in feet

2. $P = 62.4 \times H$

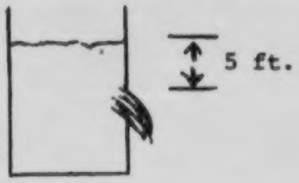
P = pounds per square foot of pressure

H = height in feet

Another way of expressing height is by the term head. In the field of hydraulics, head refers to the height in feet of water above the point in question.

For example: An opening in a side of a tank is discharging water under a head of 5 ft. This means that the head would be measured from the center line of the hole to the water surface above (See Figure 2).

FIGURE 2



Head = 5 ft.

If you will recall the example that was used when describing force and pressure, we said the height was one foot. Another way of saying this is to say the head was 1 ft. In the two foot high container, the head would be what?

(2 ft.)

The general formulas for finding pressure can now be expressed in terms of head:

1. $p \text{ (in psi)} = 0.433 \times H$

p = pounds per square inch of pressure

H = feet of head

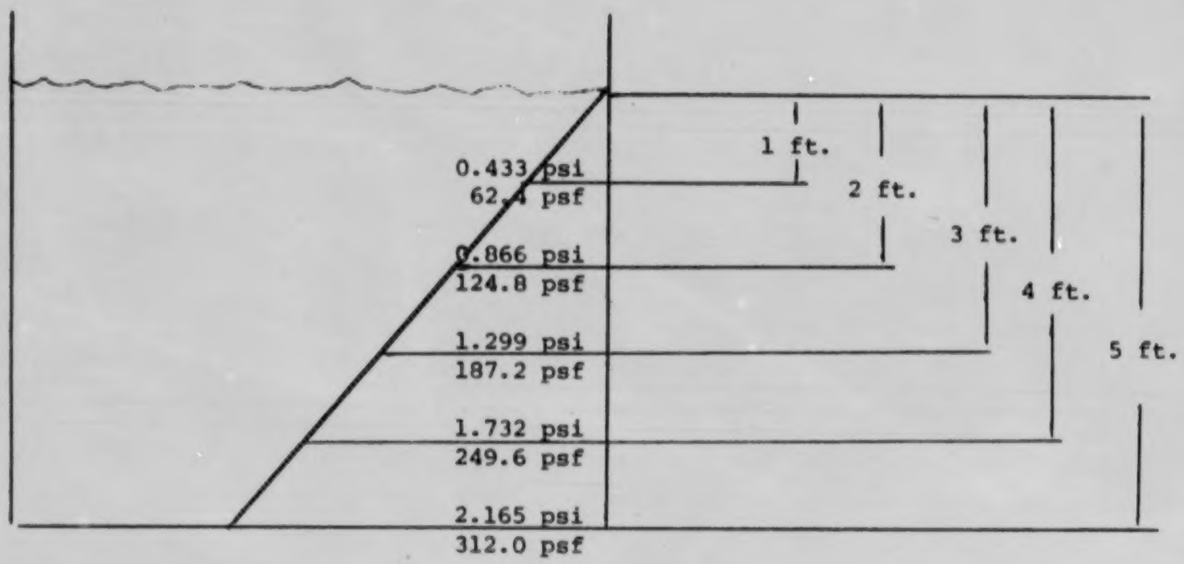
2. $p \text{ (in psf)} = 62.4 \times H$

p = pounds per square foot of pressure

H = feet of head.

Let us now determine the pressure acting on the sides of a tank five foot deep. From the diagram shown below we can see that the deeper the water is the greater the pressure.

FIGURE 3



At 0 ft. of head the pressure is 0.433 x 0 = 0 psi or 62.4 x 0 = 0 psf
1 ft. of head the pressure is 0.433 x 1 = 0.433 psi or 62.4 x 1 = 62.4 psf
2 ft. of head the pressure is 0.433 x 2 = 0.866 psi or 62.4 x 2 = 124.8 psf
3 ft. of head the pressure is 0.433 x 3 = 1.299 psi or 62.4 x 3 = 187.2 psf
4 ft. of head the pressure is 0.433 x 4 = 1.732 psi or 62.4 x 4 = 249.6 psf
5 ft. of head the pressure is 0.433 x 5 = 2.165 psi or 62.4 x 5 = 312 psf

We said earlier that the pressure caused by water is equal in all directions. This statement is only true when the head to all portions of the area is the same. In Figure 3, the pressure (2.165 psi or 312 psf) exerted on the bottom of the tank is equal at all points on the bottom since all these points have the same head. But all the points on the wall do not have the same pressure exerted on them. At the top (at 0 ft. of head) the pressure is 0 psi or 0 psf. At the bottom (5 ft. head) the pressure is 2.165 psi or 312 psf. Therefore, the average pressure exerted on a wall is:

$$\frac{0 \text{ psi} + 2.165 \text{ psi}}{2} = 1.0825 \text{ psi or } \frac{0 \text{ psf} + 312 \text{ psf}}{2} = 156 \text{ psf}$$

If the wall were four feet long, this pressure of 1.0825 psi or 156 psf would be acting over the entire 20 square foot (4 ft. x 5 ft.) area of the wall. The total force acting to push the wall would be:

$$\begin{aligned}\text{Force} &= P \times A\\ &= 156\ \text{lbs./sq. ft.} \times 20\ \text{sq. ft.}\\ &= 3120\ \text{lbs.}\end{aligned}$$

If the pressure in psi were used, the answer would be the same

$$\begin{aligned}\text{Force} &= P \times A\\ &= \frac{1.0825\ \text{lbs.}}{\text{sq. in.}} \times 5\ \text{ft.} \times 4\ \text{ft.}\\ &= \frac{1.0825\ \text{lbs.}}{\cancel{\text{sq.}}\ \cancel{\text{in.}}} \times 60\ \cancel{\text{in.}} \times 48\ \cancel{\text{in.}}\end{aligned}$$

Since 5 ft. = 60 in. $(5\ \cancel{\text{ft.}} \times \frac{12\ \text{in.}}{1\ \cancel{\text{ft.}}})$

and 4 ft. = 48 in. $(4\ \cancel{\text{ft.}} \times \frac{12\ \text{in.}}{1\ \cancel{\text{ft.}}}$

$$\begin{aligned}&= 1.0825\ \text{lbs.} \times 60 \times 48\\ &= 3117.6\ \text{lbs.}\end{aligned}$$

The formula for finding the total force acting on the side of a tank is:

$$F = 31.2\ \text{lbs./cu. ft.} \times H^2 \times L$$

F = force in pounds

H = head in feet

L = length of wall

31.2 = constant with units of lbs./cu. ft. This takes into account that the force is exerted at H/2. $(\frac{62.4\ \text{lbs.}}{\text{cu. ft.}} \times \frac{1}{2} = 31.2\ \text{lbs./cu. ft.})$

Reworking the above problem (5 ft. high tank, 4 ft. long) using the formula given above, we calculate the same answer as determined by the equation:

$$\text{Force} = P \times A$$

$$\begin{aligned}\text{Force} &= 31.2 \times H^2 \times L\\ &= \frac{31.2\ \text{lbs.}}{\text{cu. ft.}} \times (5\ \text{ft.})^2 \times 4\ \text{ft.}\\ &= \frac{31.2\ \text{lbs.}}{\cancel{\text{cu.}}\ \cancel{\text{ft.}}} \times 25\ \cancel{\text{sq.}}\ \cancel{\text{ft.}} \times 4\ \cancel{\text{ft.}}\\ &= 3120\ \text{lbs.}\end{aligned}$$

The idea that water exerts pressure equally in all directions is called Pascal's Principle. An application of this principle is in the use of gages or glass tubes in the sides of tanks to determine the depth of the fluid within. For example, if a glass tube was inserted into the side of a tank and bent up along the side of the tank, the water pressure at the hold would cause the water to enter the tube. The water would then rise until the water level in the tube would exactly equal the water level in the tank.

Since Pascal's Principle says that pressure will be exerted upward as well as downward, one can see where the warning: Never empty a tank during periods of high ground water is good advice to heed. Why? The pressure on the bottom of the tank caused by the water surrounding the tank will cause it to float if this pressure is greater than the weight of the tank. For example: What is the upward force exerted on the bottom of an empty tank 15 ft. long and 10 ft. wide if the ground water has a depth of 10 ft. above the tank bottom?

(1) Force = Pressure x Area

(2) P = 62.4 lbs./cu. ft. x Head

$$= \frac{62.4\ \text{lbs.}}{\underset{\text{sq. ft.}}{\cancel{\text{cu.}}\ \cancel{\text{ft.}}}} \times 10\ \cancel{\text{ft.}}$$

= 624 lbs./sq. ft.

(3) Area = L x W

= 15 ft. x 10 ft.

= 150 sq. ft.

Therefore:

(4) Force = P x A

$$= \frac{624\ \text{lbs.}}{\cancel{\text{sq.}}\ \cancel{\text{ft.}}} \times 150\ \cancel{\text{sq.}}\ \cancel{\text{ft.}}$$

= 93,600 lbs.

Therefore, there is a force of 93,600 lbs. on the bottom of the tank which will cause it to float. This type of force will cause floors, concrete and earth to buckle when pipes break.

For example: What unit pressure will cause a basement floor to buckle when a pipe below a basement floor breaks releasing water. The water flows upward around the basement walls and away at the ground surface 10 feet above.

(1) Pressure = 62.4 lbs./cu. ft. x Head

$$= \frac{62.4 \text{ lbs.}}{\underset{\text{sq. ft.}}{\cancel{\text{cu.}}\ \cancel{\text{ft.}}}} \times 10\ \cancel{\text{ft.}}$$

= 62.4 lbs./sq. ft. x 10

= 624 lbs./sq. ft.

These last two examples have demonstrated the usefulness of knowing some of the basic principles of hydraulics. Let us conclude this section of the module with one more example on how to apply your knowledge of hydraulics to a problem you may encounter in your work.

Example: If a gage on the side of a tank indicates that the pressure inside the tank is 3.26 psi, how high is the water level inside of the tank?

(1) P (psf) = 62.4 lbs./cu. ft. x H

(2) Converting 3.26 psi to psf

$$\frac{3.26 \text{ lbs.}}{1 \text{ sq. in.}} \times \frac{144 \text{ sq. in.}}{1 \text{ sq. ft.}} = 469.4 \text{ lbs./sq. ft.}$$

(3) P (psf) = 62.4 lbs./cu. ft. x H

469.4 lbs./sq. ft. = 62.4 lbs./cu. ft. x H

$$\frac{\ \frac{469.4 \text{ lbs.}}{\text{sq. ft.}}\ }{\frac{62.4 \text{ lbs.}}{\text{cu. ft.}}} = \text{H} \quad \text{(divide both sides of equation by 62.4 lbs./cu.ft.)}$$

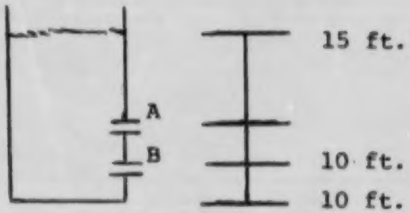
$$\frac{469.4\ \cancel{\text{lbs.}}}{\cancel{\text{sq.}}\ \cancel{\text{ft.}}} \times \frac{\overset{\text{ft.}}{1\ \cancel{\text{cu.}}\ \cancel{\text{ft.}}}}{62.4 \text{ lbs.}} = \text{H}$$

7.52 ft. = H

Therefore, the height of the water or head is equal to approximately 8 ft. (rounding off to the nearest foot).

SELF-TEST

1. Pounds is a measure of __________.	force
2. Force per unit area is called __________.	pressure
3. The pressure on the bottom of a tank three feet deep is equal to 3 x __________psi.	0.433 psi
4. If we wished to express the pressure in psf we would multiply 3 x __________psf.	62.4 psf
5. What is the head acting on point A? Point B?	Point A: 15 ft. Point B: 25 ft.



6. The formula for finding the total force acting on the side of a tank is __________.	$F = 31.2 \times H^2 \times L$

VELOCITY AND FLOW

The speed at which a substance travels is called velocity and is measured in distance per unit of time. For example, a car traveling 100 miles in two hours has a velocity of 50 miles per hour ($\frac{\text{100 miles}}{\text{2 hrs.}}$ = 50 miles per hour). A formula for velocity therefore would be:

$$\text{Velocity (in miles/hr.)} = \frac{\text{distance (miles)}}{\text{time (hours)}}$$

Likewise, flowing water has a velocity. If a particle of water travels 500 ft. in 5 minutes, the velocity is 100 ft./min.

$$\text{Velocity (ft./min.)} = \frac{\text{distance (ft.)}}{\text{time (min.)}}$$

$$= \frac{\text{500 ft.}}{\text{5 min.}}$$

$$= \text{100 ft./min.}$$

If you wish to express this velocity in ft./sec., multiply by 1 min./60 seconds. This conversion factor (1 min./60 sec.) will not change the value of the answer, it will only change the form.

$$\text{Velocity (ft./sec.)} = \text{Velocity (ft./min.)} \times \text{1 min./60 sec.}$$

$$= \frac{\text{100 ft.}}{\cancel{\text{min.}}} \quad \frac{1\ \cancel{\text{min.}}}{\text{60 sec.}}$$

$$= \frac{\text{100 ft.}}{\text{60 sec.}}$$

$$= \text{1.66 ft./sec.}$$

While velocity will tell you the speed at which water is traveling, it does not tell you how much water is passing a given point along a pipe or channel. This volume of flow past a certain point is called rate of flow. In other words, rate of flow tells the rate at which the flow moves. It is calculated as follows:

Suppose there is a channel that is one foot deep and one foot wide. How much area would one end of the channel cover? From our discussion on area in a previous module, we know that the area equals the height times the depth ($A = h \times d$). So the area of the end of the channel is one foot times one foot or one square foot. This area is the same at any point along the channel where the height is one foot and the depth is one foot. Therefore, we can say the cross sectional area of the channel is 1 sq. ft.

If the velocity of water in this channel is 1 ft. per sec., then we can say 1 sq. ft. of water in area and 1 ft. long will pass a given point each second. In other words, 1 cu. ft. of water would pass by every second. The rate of flow is 1 cu. ft. per second or 1 cfs.

We figured rate of flow by multiplying the velocity (1 ft./sec.) times the cross sectional area (1 sq. ft.). The formula is:

$$Q = V \times A$$

Where: Q = Rate of flow in cfs or cu. ft./sec.

V = velocity in ft./sec.

A = area in sq. ft.

Example 1: Find the rate of flow (Q) in a 12 inch pipe if the flow is measured at 10 ft./sec.

(1) Q (in. cfs) = V (ft./sec.) x A (sq. ft.)

(2) Area of cross section of pipe = πr^2

$= \pi (.5 \text{ ft.})^2$ since diameter of pipe = 12 in.

$r - 1/2\ D$

$r = 6$ in. or .5 ft.

$\left(6\ \cancel{in}. \times \frac{1 \text{ ft.}}{12\ \cancel{in}.}\right)$

$= \pi \times .25$ sq. ft.

$= .785$ sq. ft.

(3) Therefore: $Q = V \times A$

$= \frac{10 \text{ ft.}}{\text{sec.}} \times .785$ sq. ft.

$= 7.85$ cu. ft./sec.

Example 2: What is the velocity of water traveling through a channel 3 ft. deep and 5 ft. wide? The flow measured 10.5 cfs.

$Q = V \times A$

(1) $V = \frac{Q}{A}$

since we can divide both sides of the equation by A without changing the meaning of the equation.

(2) Cross Sectional Area of Channel = $W \times h$

$= 3 \text{ ft.} \times 5 \text{ ft.}$

$= 15$ sq. ft.

(3) $v = \frac{Q}{A}$

$$= \frac{\frac{10.5\ \text{cu. ft.}}{\text{sec.}}}{15\ \text{sq. ft.}}$$

$$= \frac{10.5\ \overset{\text{ft.}}{\cancel{\text{cu.}}\ \cancel{\text{ft.}}}}{\text{sec.}} \times \frac{1}{15\ \text{sq. ft.}}$$

$$= .7\ \text{ft./sec.}$$

Example 3: What is the average velocity of water in a 10 inch pipe if the flow is 400 gpm?

(1) $V = \frac{Q}{A}$

(2) Cross sectional area of pipe $= \pi r^2$

$= \pi\ (.416\ \text{ft.})^2$

since diameter of
pipe = 10 in.
r = 1/2 D
r = 5 in. or .416 ft.
$(5\ \cancel{\text{in.}} \times \frac{1\ \text{ft.}}{12\ \cancel{\text{in.}}})$

$= \pi \times .173$ sq. ft.

$= .545$ sq. ft.

(3) $Q\ (\text{in. cfs}) = Q\ (\text{gal./min.}) \times \frac{\text{cu. ft.}}{7.48\ \text{gal.}} \times \frac{1\ \text{min.}}{60\ \text{sec.}}$

since 1 cu. ft. =
7.48 gal. and 1 min. =
60 sec.

$$= \frac{400\ \cancel{\text{gal.}}}{\cancel{\text{min.}}} \times \frac{\text{cu. ft.}}{7.48\ \cancel{\text{gal.}}} \times \frac{1\ \cancel{\text{min.}}}{60\ \text{sec.}}$$

$$= \frac{400\ \text{cu. ft.}}{7.48 \times 60\ \text{sec.}}$$

$$= \frac{400\ \text{cu. ft.}}{448.8\ \text{sec.}}$$

$$= .89\ \text{cu. ft./sec. (cfs)}$$

(4) $V = \frac{Q}{A}$

$$= \frac{.89\ \text{cfs}}{.545\ \text{sq. ft.}}$$

$$= \frac{.89\ \overset{\text{ft.}}{\cancel{\text{cu.}}\ \cancel{\text{ft.}}}}{} \times \frac{1}{.545\ \cancel{\text{sq.}}\ \cancel{\text{ft.}}}$$

$$= 1.63\ \text{ft./sec.}$$

SELF-TEST

1. Distance per unit time is a measure of __________?	Velocity
2. The volume of water passing a certain point in a pipe is measured by what is called ________ _________ _________.	Rate of Flow
3. The formula for the rate of flow is _______?	Q = V x A

FRICTION LOSS

Ideally water flowing in a pipe downhill would encounter no resistance. That is, it would appear to flow without anything slowing it down. But due to the apparent roughness between the flowing water and the surface of the pipe in which the water flow, it does slow down. This resistance due to the friction created between the fluid and the wall of the conduit, is called friction loss.

This friction loss or loss of head caused by flow in the pipe varies as the square of the quantity of flow. In otherwords, if the flow through a pipe is doubled, the friction loss would double.

Many factors effect friction loss besides rate of flow. Some of these factors include the size of the pipe (its diameter), its length and the apparent roughness of the surface in contact with the water. This last factor of degree of pipe roughness is commonly called a C factor. High C values imply less friction. Most pipe materials have a C value from 90 - 140. (Table 1).

TABLE 1

C Factor Values for Various Types of Pipe
(Taken from Course in Applied Hydraulics p. 5-6)

Pipe Description	C
Asbestos cement	140
Brass or lead, new	140
Cast iron, uncoated, new	130
Five years old	120
Ten years old	110
Fifteen years old	100
Twenty years old	90
Thirty years old	80
Concrete, very smooth, excellent joints	140
Smooth, good joints	120
Rough	110
Corrugated	60
Steel, welded, new	130
(Same deterioration with age as for cast iron, uncoated)	

TABLE 1 CONTINUED

Pipe Description	C
Vitrified	110
Wood or wood stave	120
Wrought iron or standard galvanized steel,	
diameter 12" and larger	110
4" to 12"	100
4" and smaller	80

In Table 2, are found head or friction losses for 100 ft. lengths of pipe of varying sizes for a C factor of 100. For example, to find the head loss that occurs in 100 ft. of 3-in. pipe for a flow of 150 gpm follow the U.S. gpm column to 150, then moving across the "Loss in ft." column for 3-in. pipe. The head loss is read as 10.5 ft. Multipling this figure by 0.433 yields a 4.55 psi loss.

Thus, if the pressure in a main where a 3-in. tap is made is 25 psi, the pressure 100 ft. away at a point where a service might enter a house, for example, would be only 20.45 psi (25 minus 4.55) when the flow through the main is 150 gpm. For 200 ft. of pipe the friction loss would be twice as much and five times as much for 500 ft. of pipe if the average flow rate were maintained at 150 gpm.

If a pipe has a C factor of other than 100, one can adjust the C factor to 100 by multiplying the flow by 100/c and then looking up the head loss in the table with the new flow value. For example, if a pipe has a C factor of 75 and a diameter of 3 inches with a flow of 150 gpm., the adjusted flow rate would be $150 \times \frac{100}{75}$ or 200 gpm. Entering the table at 200 gpm and crossing over to the 3-in. pipe, one sees that there is a loss of 17.8 ft. Thus the rougher pipe losses 7.3 (17.8 - 10.5) ft. of head for each 100 ft. of pipe used.

In addition to friction losses caused by flow through straight sections of pipe, water can be slowed by passing through fittings, orifices and curves in pipes.

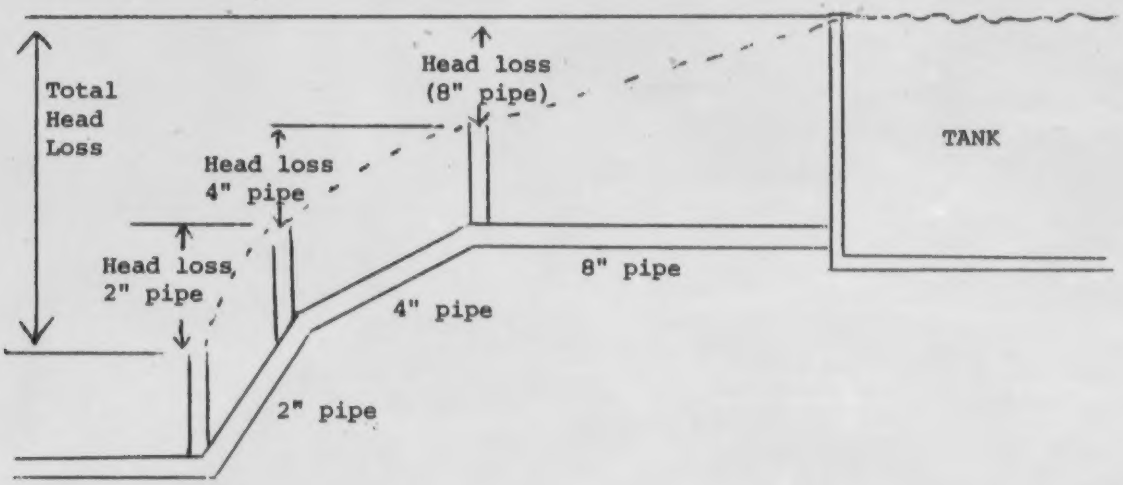
SELF-TEST

1. Friction loss is affected by 1) __________, 2) __________, 3) __________ and 4) __________.	1) Rate of Flow 2) Diameter of pipe 3) Length 4) Roughness of pipe
2. The C factor is a measure of __________?	degree of pipe roughness
3. There is __________ friction in a pipe with a C factor of 100 than one with a C factor of 150.	More

HYDRAULIC GRADIENT

In order to determine the flow of water in pipelines, one should be aware of the concept of hydraulic gradient. If vertical glass tubes are inserted at various points along a pipe in which water is flowing, the pressure in the pipe will cause water to rise in each of the glass tubes. A line drawn from one tube to the next connecting the points to which the water rises in each is defined as the hydraulic grade line for the pipe. If the pipe is uniform in size and there are no branch lines along the line, then the hydraulic grade line would be a straight line. If a pipeline of different pipe sizes were examined one can see that the hydraulic grade line is a slope. (See Figure 4). The gradient of this slope becomes steeper as the pipe becomes smaller. The slope or steepness of the hydraulic grade line, is the head loss as given in the Friction Loss Table for the particular pipe plus the difference in elevation of the two ends of the pipe divided by the horizontal distance.

FIGURE 4



HYDRAULIC FORCES

At the beginning of this module, we mentioned that water will exert a pressure on the container it is in. This pressure is caused by gravity. In pipelines, water creates a great deal of pressure because this water is confined in the pipe under a considerable head. This pressure can act on the pipe to cause the pipe to stretch or expand. Thus the pipe must be strong enough to resist this vertical and horizontal expansion.

This pressure caused by water will also act on closed valves at the end of a line, caps on risers in the line and 90 degree bends in the line. Therefore these units must be securely anchored so that the water pressure will not blow them off the line. Caps and closed valves are usually fastened to pipelines with flange bolts. Upward 90 degree bends are usually anchored by fastening sufficient concrete to the pipeline to counteract any force created by the water. Horizontal bends in pipes are normally blocked against undisturbed earth so that it can not move.

Not only will normal pressure exert force, but a valve closed too rapidly will create force. When the valve is closed, the water comes to a sudden stop, thus causing waves of high pressure to oscillate back and forth in the isolated pipe section. That is called "water hammer."

TABLE 2

FRICTION LOSS OF WATER PER 100 FEET LENGTH OF PIPE (INSIDE DIAMETER)

Based on Williams & Hazen Formula Using Constant 100
Sizes of Standard Pipe in Inches

1/2" Pipe		3/4" Pipe		1" Pipe		1-1/4" Pipe		1-1/2" Pipe		2" Pipe		2-1/2" Pipe		3" Pipe		4" Pipe		5" Pipe		6" Pipe		U.S. Gals. Per Min.
Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	
2.10	7.4	1.20	1.9																			2
4.21	27.0	2.41	7.0	1.49	2.14	.86	.57	.63	.26													4
6.31	57.0	3.61	14.7	2.23	4.55	1.29	1.20	.94	.56	.61	.20											6
8.42	98.0	4.81	25.0	2.98	7.8	1.72	2.03	1.26	.95	.82	.33	.52	.11									8
10.52	147.0	6.02	38.0	3.72	11.7	2.14	3.05	1.57	1.43	1.02	.50	.65	.17	.45	.07							10
		7.22	53.0	4.46	16.4	2.57	4.3	1.89	2.01	1.23	.79	.78	.23	.54	.10							12
		9.02	80.0	5.60	25.0	3.21	6.5	2.36	3.00	1.53	1.08	.98	.36	.68	.15							15
		10.84	108.2	6.69	35.0	3.86	9.1	2.83	4.24	1.84	1.49	1.18	.50	.82	.21							18
		12.03	136.0	7.44	42.0	4.29	11.1	3.15	5.20	2.04	1.82	1.31	.61	.91	.25	.51	.06					20
				9.30	64.0	5.36	16.6	3.80	7.30	2.55	2.73	1.63	.92	1.13	.38	.64	.09					25
				11.15	89.0	6.43	23.0	4.72	11.0	3.06	3.84	1.96	1.29	1.36	.54	.77	.13	.49	.04			30
				13.02	119.0	7.51	31.2	5.51	14.7	3.57	5.10	2.29	1.72	1.59	.71	.89	.17	.57	.06			35
				14.88	152.0	8.58	40.0	6.30	18.8	4.08	6.6	2.61	2.20	1.82	.9[illegible]	1.02	.22	.65	.08			40
						9.65	50.0	7.08	23.2	4.60	8.2	2.94	2.80	2.04	1.15	1.15	.28	.73	.09			45
						10.72	60.0	7.87	28.4	5.11	9.9	3.27	3.32	2.27	1.38	1.28	.34	.82	.11	.57	.04	50
						11.78	72.0	8.66	34.0	5.62	11.8	3.59	4.01	2.45	1.58	1.41	.41	.90	.14	.62	.05	55
						12.87	85.0	9.44	39.6	6.13	13.9	3.92	4.65	2.72	1.92	1.53	.47	.98	.16	.68	.06	60
						13.92	99.7	10.23	45.9	6.64	16.1	4.24	5.4	2.89	2.16	1.66	.53	1.06	.19	.74	.076	65
						15.01	113.0	11.02	53.0	7.15	18.4	4.58	6.2	3.18	2.57	1.79	.63	1.14	.21	.79	.08	70
						16.06	129.0	11.80	60.0	7.66	20.9	4.91	7.1	3.33	3.00	1.91	.73	1.22	.24	.85	.10	75
						17.16	145.0	12.59	68.0	8.17	23.7	5.23	7.9	3.63	3.28	2.04	.81	1.31	.27	.91	.11	80
						18.21	163.8	13.38	75.0	8.68	26.6	5.56	8.1	3.78	3.54	2.17	.91	1.39	.31	.96	.12	85
						19.30	180.0	14.71	84.0	9.19	29.4	5.88	9.8	4.09	4.08	2.30	1.00	1.47	.34	1.02	.14	90
								14.95	93.0	9.70	32.6	6.21	10.8	4.22	4.33	2.42	1.12	1.55	.38	1.08	.15	95
8" Pipe								15.74	102.0	10.21	35.8	6.54	12.0	4.54	4.96	2.55	1.22	1.63	.41	1.13	.17	100
								17.31	122.0	11.23	42.9	7.18	14.5	5.00	6.0	2.81	1.46	1.79	.49	1.25	.21	110
								18.89	143.0	12.25	50.0	7.84	16.8	5.45	7.0	3.06	1.17	1.96	.58	1.36	.24	120
								20.46	166.0	13.28	58.0	8.48	18.7	5.91	8.1	3.31	1.97	2.12	.67	1.47	.27	130
.90	.08							22.04	190.0	14.30	67.0	9.15	22.3	6.35	9.2	3.57	2.28	2.29	.76	1.59	.32	140
.96	.09									15.32	76.0	9.81	25.5	6.82	10.5	3.82	2.62	2.45	.88	1.70	.36	150
1.02	.10									16.34	86.0	10.46	29.0	7.26	11.8	4.08	2.91	2.61	.9[illegible]	1.82	.40	160
1.08	.11	10" Pipe								17.36	96.0	11.11	34.1	7.71	13.3	4.33	3.26	2.77	1.08	1.92	.45	170
1.15	.13									18.38	107.0	11.76	35.7	8.17	14.0	4.60	3.61	2.94	1.22	2.04	.50	180
1.21	.14									19.40	118.0	12.42	39.6	8.63	15.5	4.84	4.01	3.10	1.35	2.16	.55	190
1.28	.15									20.42	129.0	13.07	43.1	9.08	17.8	5.11	4.4	3.27	1.48	2.27	.62	200
1.4[illegible]	.16	.90	.06							22.47	154.0	14.38	52.0	9.99	21.3	5.62	5.2	3.59	1.77	2.50	.73	220

TABLE 2
(Continued)

1/2" Pipe		3/4" Pipe		1" Pipe		1-1/4" Pipe		1-1/2" Pipe		2" Pipe		2 1/2" Pipe		3" Pipe		4" Pipe		5" Pipe		6" Pipe		U.S. Gals. Per Min.
Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	
1.53	.22	.98	.07							24.51	182.0	15.69	61.0	10.89	25.1	6.13	6.2	3.92	2.08	2.72	.87	240
1.66	.25	1.06	.08							26.55	211.0	16.99	70.0	11.80	29.1	6.64	7.2	4.25	2.41	2.95	1.00	260
1.79	.28	1.15	.09									18.30	81.0	12.71	33.4	7.15	8.2	4.58	2.77	3.18	1.14	280
1.91	.32	1.22	.11									19.61	92.0	13.62	38.0	7.66	9.3	4.90	3.14	3.40	1.32	300
2.05	.37	1.31	.12	12" Pipe								20.92	103.0	14.52	42.8	8.17	10.5	5.23	3.54	3.64	1.47	320
2.18	.41	1.39	.14									22.22	116.0	15.43	47.9	8.68	11.7	5.54	3.97	3.84	1.62	340
2.30	.45	1.47	.15			14" Pipe						23.53	128.0	16.34	53.0	9.19	13.1	5.97	4.41	4.08	1.83	360
2.43	.50	1.55	.17	1.08	.069							24.84	142.0	17.25	59.0	9.69	14.0	6.19	4.86	4.31	2.00	380
2.60	.54	1.63	.19	1.14	.075							26.14	156.0	18.16	65.0	10.21	16.0	6.54	5.4	4.55	2.20	400
2.92	.68	1.84	.23	1.28	.95									20.40	78.0	11.49	19.8	7.35	6.7	5.11	2.74	450
3.19	.82	2.04	.28	1.42	.113	1.04	.06							22.70	98.0	12.77	24.0	8.17	8.1	5.68	2.90	500
3.52	.97	2.24	.33	1.56	.135	1.15	.07							24.96	117.0	14.04	28.7	8.99	9.6	6.25	3.96	550
3.84	1.14	2.45	.39	1.70	.159	1.25	.08							27.23	137.0	15.32	33.7	9.80	11.3	6.81	4.65	600
4.16	1.34	2.65	.45	1.84	.19	1.37	.09									16.59	39.0	10.62	13.2	7.38	5.40	650
4.46	1.54	2.86	.52	1.99	.22	1.46	.10									17.87	44.9	11.44	15.1	7.95	6.21	700
4.80	1.74	3.06	.59	2.13	.24	1.58	.11	16" Pipe								19.15	51.0	12.26	17.2	8.50	7.12	750
5.10	1.90	3.26	.66	2.27	.27	1.67	.13									20.42	57.0	13.07	19.4	9.08	7.96	800
5.48	2.20	3.47	.75	2.41	.31	1.79	.14	1.36	.08							21.70	64.0	13.89	21.7	9.65	8.95	850
5.75	2.46	3.67	.83	2.56	.34	1.88	.16	1.44	.084	20" Pipe						22.98	71.0	14.71	24.0	10.20	10.11	900
6.06	2.87	3.88	.91	2.70	.38	2.00	.18	1.52	.095									15.52	26.7	10.77	11.20	950
6.38	2.97	4.08	1.03	2.84	.41	2.10	.19	1.60	.10	1.02	.04							16.34	29.2	11.34	12.04	1000
7.03	3.52	4.49	1.19	3.13	.49	2.31	.23	1.76	.12	1.12	.04							17.97	34.9	12.48	14.55	1100
7.66	4.17	4.90	1.40	3.41	.58	2.52	.27	1.92	.14	1.23	.05							19.61	40.9	13.61	17.10	1200
8.30	4.85	5.31	1.62	3.69	.67	2.71	.32	2.08	.17	1.33	.06									14.72	18.4	1300
8.95	5.50	5.71	1.87	3.98	.73	2.92	.36	2.24	.19	1.43	.06	24" Pipe								15.90	22.60	1400
9.58	6.24	6.12	2.13	4.26	.89	3.15	.41	2.39	.21	1.53	.07									17.02	25.60	1500
10.21	7.00	6.53	2.39	4.55	.98	3.34	.47	2.56	.24	1.63	.08			10" Pipe						18.10	26.9	1600
11.50	8.78	7.35	2.95	5.11	1.21	3.75	.58	2.87	.30	1.84	.10	1.28	.04									1800
12.78	10.71	8.16	3.59	5.68	1.49	4.17	.71	3.19	.37	2.04	.12	1.42	.05									2000
14.05	12.78	8.98	4.24	6.25	1.81	4.59	.84	3.51	.44	2.25	.15	1.56	.06									2200

2
(Continued)

1/2" Pipe		3/4" Pipe		1" Pipe		1-1/4" Pipe		1-1/2" Pipe		2" Pipe		2-1/2" Pipe		3" Pipe		4" Pipe		5" Pipe		6" Pipe		
Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	Vel. 'per Sec.	Loss in Feet	U.S. Gals. Per Min.
15.32	14.2	9.80	5.04	6.81	2.08	5.00	.99	3.83	.52	2.45	.17	1.70	.07	1.09	.02							2400
		10.61	5.81	7.38	2.43	5.47	1.17	4.15	.60	2.66	.20	1.84	.08	1.16	.022							2600
		11.41	6.70	7.95	2.75	5.84	1.32	4.47	.68	2.86	.23	1.98	.09	1.27	.03							2800
		12.24	7.62	8.52	3.15	6.01	1.49	4.79	.78	3.08	.27	2.13	.10	1.37	.037							3000
		13.05	7.8	9.10	3.51	6.68	1.67	5.12	.88	3.27	.30	2.26	.12	1.46	.047							3200
		14.30	10.08	9.95	4.16	7.30	1.97	5.59	1.04	3.59	.35	2.49	.14	1.56	.047							3500
		15.51	13.4	10.80	4.90	7.98	2.36	6.07	1.20	3.88	.41	2.69	.17	1.73	.05							3800
				11.92	5.88	8.76	2.77	6.70	1.44	4.29	.49	2.99	.20	1.91	.07							4200
				12.78	6.90	9.45	3.22	7.18	1.64	4.60	.56	3.20	.22	2.04	.08							4500
				14.20	8.40	10.50	3.92	8.01	2.03	5.13	.68	3.54	.27	2.26	.09							5000
						11.55	4.65	8.78	2.39	5.64	.82	3.90	.33	2.50	.11							5500
						12.60	5.50	9.58	2.79	6.13	.94	4.25	.38	2.73	.13							6000
						13.65	6.45	10.39	3.32	6.64	1.10	4.61	.45	2.96	.15							6500
						14.60	7.08	11.18	3.70	7.15	1.25	4.97	.52	3.18	.17							7000
								12.78	4.74	8.17	1.61	5.68	.66	3.64	.23							8000
								14.37	5.90	9.20	2.01	6.35	.81	4.08	.28							9000
								15.96	7.19	10.20	2.44	7.07	.98	4.54	.33							10000
										12.25	3.41	8.50	1.40	5.46	.48							12000
										14.30	4.54	9.95	1.87	6.37	.63							14000
												11.38	2.40	7.28	.81							16000
												12.76	2.97	8.18	1.02							18000
												14.20	3.60	9.10	1.23							20000

SELF-TEST

1. The gradient line of a pipe 2 in. in diameter is __________ than a pipe 4 in. in diameter.	Steeper
2. Pressure caused by water will cause __________ and __________ on risers to break open if not properly anchored.	Closed valves at end of lines, Caps
3. Valves closed suddenly will cause __________ __________.	Water Hammer

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. Course in Applied Hydraulics for Water and Wastewater Personnel, Sponsored by Michigan Section AWWA, Michigan Water Pollution Control Association and Michigan Department of Public Health.
2. Manual of Instruction for Water Treatment Plant Operators. New York State Department of Health, Office of Public Health Education, Albany, N.Y. pp. 19-40.
3. Manual of Water Utility Operations. Texas Water Utilities Association, Austin, TX pp. 338-380.
4. Operation of Wastewater Treatment Plants. California Water Pollution Control Association, Environmental Protection Agency, Sacramento, CA Chapter 15, pp. 15-49 to 15-57.
5. Water Distribution Operator Training Handbook. AWWA pp. V-1 to V-9.

POST-EVALUATION (10 pts. each, except Question 1 is worth 20 pts.)

1. What is the Rate of Flow of water in a 12 inch pipe if the velocity of the water is measured at 5.7 ft. per second (fps)? (in gpm).

2. What is the friction loss which occurs in 100 ft. of 2.5" pipe if the flow is 125 gpm? The C factor of the pipe is 125 and the pressure in the main where the 2.5" pipe is attached is 75 psi? B) What is the pressure of the water where it enters a house?

3. What is the C factor?

4. Which has a higher C factor:
   a) New Brass or lead pipe
   b) Cast iron pipe thirty years old
   c) Galvanized steel pipe with a diameter of 4" and smaller
   d) Concrete pipe very smooth, excellent joints
   e) B and C
   f) A and D

5. Pressure caused by water will cause __________ to burst if not strongly anchored?
   a) closed valves
   b) open valves
   c) straight pipes
   d) all of the above
   e) none of above

6. Oscillating waves of high pressure caused by valves closed too rapidly is called:
   a) nothing because these waves are not created
   b) knocking
   c) water hammer
   d) closing the valve too rapidly

7. If a 10 inch pipe is closed at the end by a cap, what is the total force on the cap when the head on the pipe center is 100 ft.?

8. Force is measured in:
   a) tons
   b) tons per ft.
   c) kilograms
   d) kilogram per sq. meter
   e) kilogram per meter
   f) A and C
   g) B and E

9. Standing water in a square conduit will exert pressure
   a) upward
   b) downward
   c) horizontally in one direction
   d) in all directions

ANSWERS

1. 2,000 gallons per minute
2. a) 5.196 psi b) 69.8 psi
3. The C factor is a measurement of the roughness of a pipe.
4. F
5. A
6. C
7. 3,401.7 lbs.
8. F
9. D

MODULE 7

SELF-INSTRUCTIONAL

Paul Hummel - NMSU

CHLORINATION

PREREQUISITES: Module One - Basic Mathematics
Module Two - Basic Chemistry

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. True or False (5 pts. each)
   a. Chlorine is used to sterilize water.
   b. Chlorine is highly flammable.
   c. Dry chlorine is corrosive at high temperatures.
   d. The amount of chlorine needed to react with hydrogen sulfide, iron nitrates and organic matter present in the water is called the chlorine demand.
   e. Temperature, time, concentration and pH affect the action of chlorine.
   f. Chlorine gas is lighter than air.
   g. Prechlorination means that chlorine is applied after treatment and before the water is delivered to the distribution system.
   h. The fusible safety plugs in chlorine cylinders are designed to melt at 212°F to prevent explosion of the cylinders.
   i. Liquid chlorine (gas under pressure), calcium hypochlorite, and sodium hypochlorite are the three common sources of chlorine as used in waterworks.
   j. Chlorine may be used up by substances in the water and so may be rendered ineffective.

2. Disease producing bacteria are called: (10 points)
   a. Saprophytes
   b. Facultative
   c. Parasitic
   d. Pathogenic
   e. Coliform

3. An operator should never enter a room containing high concentrations of chlorine gas without: (10 points)
   a. Help standing by
   b. A self-contained air or oxygen supply
   c. Notifying proper authorities
   d. None of the above
   e. All of the above
   f. A and B

4. If 2 mg./l. of chlorine are applied to a certain water at a well and a sample from the distribution system is found to have a residual of 0.5 mg./l., what is the chlorine demand? (30 pts.)

ANSWERS

1. a. F
    b. F
    c. T
    d. T
    e. T
    f. F
    g. F
    h. F
    i. T
    j. T

2. d

3. e

4. 1.5 mg./l.

INTRODUCTION

Water contains microorganisms from many sources. Some of the organisms are harmful to human health. These diseases causing organisms must be destroyed before water can be put into the distribution system for public consumption. This module will deal with the ways that these organisms can be destroyed, that is through chlorination. It will also describe safety procedures and first aid measures which you should be thoroughly familiar with.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the following concepts:

1. The principles of water disinfection with chlorine
2. Determine chlorine dosages
3. Handle chlorine safely

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

CHLORINE

Chlorine, discovered in 1774, exists as a solid, liquid or gas. At atmospheric pressure and at temperatures less than -149.76°F, chlorine exists as a solid. From this temperature to -30.1°F, and at normal atmospheric pressure this element takes the form of a liquid. Above this temperature it exists as a gas.

The word chlorine and the symbol Cl comes from the Greek word "chloros" meaning green, the characteristic color of the gas. Commercial chlorine is manufactured by the electrolysis of a sodium chloride solution. The gas produced by this process is dried and purified, then liquified by compression and refrigeration.

Chlorine gas is not explosive or flammable and is 2 1/2 times heavier than air. It is soluble in water to a maximum of one percent at 49.2°F. When chlorine gas is dissolved in water it will form a solid crystalline hydrate at temperatures less than 49.2°F. This solid is sometimes called "chlorine ice" which may cause problems in some gas chlorinators.

At normal temperatures dry chlorine is not corrosive but at higher temperatures it is. Chlorine is also very corrosive if moisture is present in it.

This element has a characteristic irritating odor and is poisonous. At a concentration of 3.5 ppm, it is barely detectable as an odor. At 30.2 ppm it will cause coughing and at 50 ppm it can be fatal in 30 to 60 minutes.

SELF-TEST

1. Chlorine can combine with water in gas chlorinators to form a crystalline hydrate called __________?	Chlorine ice
2. Dry chlorine is corrosive at __________ temperatures.	High
3. Chlorine can be fatal at __________ppm in 30 to 50 minutes.	50

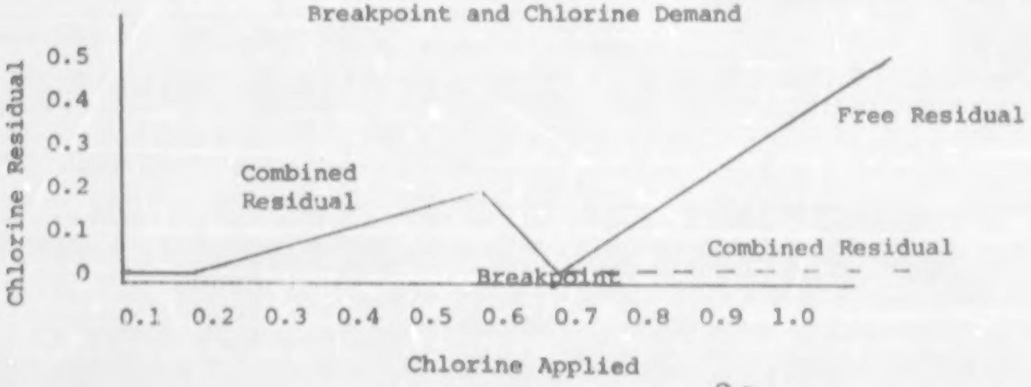
USE OF CHLORINE

Clorine is used in a water treatment plant as a disinfectant. This means that it is used to kill pathogenic (disease-carrying) organisms. Disinfectant is not the same as sterilization. Sterilization means that all the microorganisms are removed or destroyed. The disinfection of water is sufficient to minimize the health hazards caused by pathogens. While sterilization will also kill pathogens, it is unneccessary and impractical.

To disinfect water, sufficient chlorine must be added to react with all the compounds present in raw water and still leave enough chlorine to destroy bacteria. Chlorine is a very active chemical agent and will react with any hydrogen sulfide, manganese, iron, organic matter, and nitrates present in the water. The amount of chlorine needed to react with these substances is called the chlorine demand. Extra chlorine must be added over the chlorine demand to kill bacteria. Combined chlorine will also kill bacteria, but requires more time. This extra amount is called the free residual chlorine.

Since the quantity of the above mentioned substances will vary in each water source, the amount of chlorine that should be added to the water will vary. Thus chlorine demand is equal to the amount of chlorine added minus that remaining after a period of time, generally 30 minutes, or Chlorine Demand = Chlorine Dose - Chlorine Residual.

The practice of adding free residual chlorine is often called breakpoint chlorination. This term comes from the characteristic curve shown in the following diagram. However many waters do not have this breakpoint. Therefore the term free residual chlorine is prefered because it implies that enough chlorine has been added to produce free residual regardless of whether there has been a breakpoint or not.



SELF-TEST

1.	To kill all microorganisms is called __________.	Sterilization
2.	To kill only the pathogenic organisms is called __________.	Disinfection
3.	Chlorine is a __________.	Disinfectant
4.	The amount of chlorine needed to react with manganese, iron nitrates, and organic matter is called __________.	Chlorine demand
5.	Extra chlorine added to the water, over the amount needed to react with manganese, iron and nitrates is called __________.	Free Residual Chlorine

FACTORS AFFECTING CHLORINATION

Not only will iron, manganese, nitrates,hydrogen sulfide and organic matter affect the amount chlorine needed to disinfect water but there are other factors which influence chlorination. Some of the factors are:

1. Suspended solids - These may shield bacteria from the destructive action of chlorine.
2. Ammonia - This compound reacts with free chlorine to form a chlorine compound having a less effective disinfecting quality than free chlorine itself. This compound is called combined chlorine or chloramines.
3. The pH value of water - Waters of low pH and alkalinity are the easiest to disinfect.
4. Temperature, time and concentration - These factors affect the rapidity and effectiveness of disinfection. Time and concentration determine the amount of reaction time available for disinfection, while temperature affects the disinfecting action of residual chlorine. At lower temperatures, bacteria kill tends to be slower than at higher temperatures.

SELF-TEST

1. Why is it important to remove most of the suspended solids in water before chlorination?	These particles may shield bacteria from the action of chlorine.
2. Waters of __________ pH and alkalinity are the hardest to disinfect?	High
3. At lower temperatures, bacteria are killed __________ than at higher temperatures.	Slower

CHLORINATION PRACTICES

Chlorine can be added to the water at various times in the treatment process. If it is applied before other treatment processes, such as coagulation, the practice is called pre-chlorination. Applied after treatment processes, it is called post-chlorination. If an excess of chlorine is added, greater than needed for disinfection, the practice is called super-chlorination. Dechlorination is that practice in which substances are added to remove residual chlorine. Usually when a plant superchlorinates the water they dechlorinate the water to maintain the desired residual. Dechlorinating substances include sulfur dioxide, sodium bisulfite, sodium sulfite, sodium thio-sulfate and activated carbon.

OTHER DISINFECTANTS

Other substances beside chlorine gas can be used to disinfect water. These substances such as sodium or calcium hypochlorinate and chlorine dioxide are compounds of chlorine and are usually added to the water as a solution.

Some non-chlorine compounds which can be used to disinfect water include ozone, silver, bromine and iodine. Ultraviolet light will also kill pathogenic organisms. The use of these substances is limited because of their impractibility and higher costs.

SELF-TEST

1. Chlorine added to the water before coagulation is called __________?	Pre-chlorination
2. Sulfur dioxide, sodium thiosulfate and activated carbon are __________ substances.	Dechlorinating
3. Name two non-chlorine substances which can be used to disinfect the water.	1. Ozone 2. Silver 3. Bromine 4. Iodine 5. Ultraviolet Light

HAZARDS OF Cl_2

Chlorine can be an extremely dangerous chemical if not handled with respect. Therefore, you should know the proper way to handle it and what to do in case of an emergency.

One can usually tell if there is a chlorine leak because of the characteristic sharp odor of this element. A chlorine leak detector may also be installed in the area of chlorinator. Therefore, it is usually possible to get out of a gas area before serious harm is suffered. Inhaling chlorine will cause severe irritation of the throat, sneezing and production of great quantities of saliva. This is usually followed by coughing, retching and vomiting, and difficulty in breathing. Liquid chlorine causes severe irritation and blistering on contact with the skin. If a person has been overcome by chlorine gas, first carry the patient away from the gas area. Remove any clothing contaminated with liquid. Keep the patient warm and quiet. Then call a doctor and the fire department. After this, begin the appropriate treatment.

If chlorine has entered the eyes, hold the eyelids apart and flush with large quantities of lukewarm running water. Continue to flush for about fifteen minutes. If the chlorine has gotten on the skin, get the patient under a shower immediately, clothes and all. Remove the clothes while the shower is running and wash the affected areas with large quantities of soap. In no case, except under the direction of a physician, should you attempt to apply salves, ointments or other medication to the affected areas.

If a person has inhaled chlorine and is breathing, put him in a comfortable position, keep him warm and quiet. If he has stopped breathing, apply artificial respiration immediately. Milk, chewing gum or drinking spirits of peppermint will help relieve throat irritation from chlorine exposure.

While the above paragraphs describe first aid measures to take in case of chlorine exposure, the best first aid measure is PREVENTION. Know the location and the uses of the various pieces of protective equipment. Keep this equipment in tip-top shape and in its proper place. Have your fire department examine your chlorine handling facilities and safety equipment so that they will be aware of the possible dangers and what kind of equipment you have.

When entering a room that may contain chlorine gas, open the door slightly and check for the smell of chlorine. Never go into a room containing gas with harmful concentrations in the air without a self-contained air supply, protective clothing and help standing by. If you find yourself in a chlorine atmosphere, take short shallow breaths because recovery from exposure depends on the amount of chlorine inhaled. So it is important to keep it as small as possible.

CHLORINE CONTAINERS

Chlorine may be purchased in cylinders containing the chemical in either its gas or liquid state. One should handle these cylinders carefully so that there is no accidental spillage of chlorine. The following are some safety precautions which will help reduce the potential danger associated with handling these containers.

1. Chlorine gas lines and chlorinators should have a higher temperature than the chlorine cylinders. This will prevent the gas from reliquifing after it leaves the cylinder.
2. Chlorine containers should be stored at moderate temperatures and never dropped or bumped. The containers should have the protective valve caps on them when not in use. The valves should be kept closed on empty containers, and full ones when not in use.
3. Never use a flame or blow-torch on a container. Directly applied heat will melt the fusible metal safety plugs designed to soften or melt between 158°F and 165°F. Direct heat will also cause the dry chlorine to burn producing ferric chloride. This process reduces the thickness of the steel and increases cylinder pressure possible rupturing the cylinder.

CHLORINE LEAKS

Chlorine leaks must be taken care of immediately or they will become worse. When repairing leaks only trained men wearing proper safety equipment should undertake to repair the leak. All others should leave the danger area. If the leak is large, obtain police help to warn and evacuate everyone in adjacent areas.

CALCULATIONS

While some examples of plant calculations involving chlorine were given in another module, let us examine some specific examples of how to determine chlorine dosage. Study the following examples:

A. Chlorine Dosage.

If it is known that the chlorine demand of your water source is 2.5 mg./l. and that a residual of 0.5 mg./l. must be maintained, what is the amount which must be added to satisfy the demand and maintain the desired residual?

$$\begin{aligned} \text{Dosage} &= \text{Demand} + \text{Residual} \\ &= 2.5 \text{ mg./l.} + 0.5 \text{ mg./l.} \\ &= 3.0 \text{ mg./l.} \end{aligned}$$

If you have applied a dosage of 2.0 mg./l. and you know that the demand is 1.0 mg./l., what is the probable residual?

$$\begin{aligned} \text{Residual} &= \text{Dosage} - \text{Demand} \\ &= 2.0 \text{ mg./l.} - 1.0 \text{ mg./l.} \\ &= 1.0 \text{ mg./l.} \end{aligned}$$

Chlorine dosage is calculated by using the pounds of chlorine fed and the pounds of water pumped. The formula for the calculations is as follows:

$$\text{mg./l. applied} = \frac{\text{lbs. } Cl_2}{\text{lbs. water in millions}}$$

B. Determination of lbs. to be fed

If chlorine gas is used, the pounds fed can be determined by weighing the cylinders on platform scales. If a compound other than chlorine gas is used, the pounds of chlorine must be calculated. For example: 8 pounds of 70% hypochlorite is equal to 5.6 lbs. of chlorine.

$$\begin{aligned} \text{lbs. of chlorine} &= \% \times \text{lbs. of hypochlorite} \\ &= .70 \times 8 \\ &= 5.6 \text{ lbs. } Cl_2 \end{aligned}$$

Since hypochlorite is a powder and must be put in solution, one must be able to calculate the lbs. of Cl_2 per a given volume of solution. This can be done as follows.

5 lbs. of 70% hypochlorite power are dissolved in 25 gallons of water and 10 gallons of the solution are used. How many pounds of Cl_2 are in the 10 gallons of solution?

1) lbs. Cl_2 = % x lbs. of hypochlorite
= .70 x 5 lbs.
= 3.5 lbs. Cl_2

2) lbs. Cl_2 per gallon solution $= \dfrac{\text{lbs. } Cl_2}{\text{volume of water}}$

$$= \frac{3.5 \text{ lbs. } Cl_2}{25 \text{ gals.}}$$

= 0.14 lbs. Cl_2 per gallon of solution

3) lbs. Cl_2 per given volume of solution = Given volume x lbs. Cl_2 per gal.
= 10 gals. x 0.14 lbs. Cl_2/gal.
= 1.4 lbs. Cl_2 in 10 gals. of solution

If a solution of hypochlorite powder is made up with a known percentage of hypochlorite, the pounds of chlorine are calculated as follows:

Nine gallons of 20% hypochlorite solution weighing 15 lbs. per gallon are applied, what is the weight of the chlorine?

1) Total weight of a given percentage of solution = number of gallons x weight per gal.
= 9 ~~gallons~~ x 15 lbs/~~gallons~~
= 135 lbs.

2) lbs. of Cl_2 = % x weight
= .20 x 135 lbs.
= 27 lbs.

If 9 gallons of 20% hypochlorite weighs 15 lbs. per gallon is diluted to 50 gallons with water and seven gallons of this diluted solution are used, how many lbs.of Cl_2 are used?

1) Total weight of given percentage of solution = number of gallons x weight per gal.

= 9 ~~gal~~ x 15 lbs/~~gal~~

= 135 lbs.

2) lbs. of Cl_2 = % x weight

= .20 x 135 lbs.

= 27 lbs. Cl_2

3) lbs Cl_2 per gallon = lbs. Cl_2/ volume of water

$$= \frac{27 \text{ lbs. } Cl_2}{50 \text{ gals}}$$

= 0.54 lbs/gallon Cl_2

4) lbs. Cl_2 used = Given volume x lbs. Cl_2/gal

= 7 ~~gal~~ x 0.54 lbs/~~gal~~

= 3.78 lbs. Cl_2

PRACTICE PROBLEMS

1. If 3 mg./l. of chlorine are applied to a certain water at a well and a sample from the distribution system is found to have a residual of 1.25 mg./l., what is the chlorine demand?

2. If a certain water is known to have a chlorine demand of 2.75 mg./l. and it is desired to maintain a residual of 0.25 mg./l., how much chlorine should be applied?

3. If 20 lbs. of chlorine are applied to 2,000,000 gallons of water, what is the applied chlorine in mg./l.?

4. If 15 lbs. of chlorine are applied to water at a well pumping 500 gallons per minute for 8 hours, what is the applied chlorine in mg./l.?

5. It is desired to apply 5 mg./l. of chlorine at a well pumping 500 gallons per minute.
   a. How many lbs. of chlorine would be used in one day?
   b. If 20% sodium hypochlorite weighing 15 lbs. per gallon is used as a source of chlorine, how many gallons would be used per day?
   c. How many pounds of 75% calcium hypochlorite would be used in one day?

ANSWERS TO PRACTICE PROBLEMS

1. 1.75 mg./l. chlorine demand
2. 3.0 mg./l. chlorine dosage
3. 1.20 mg./l. chlorine dosage
4. 7.5 mg./l. chlorine dosage
5. a) 30 lbs. of chlorine
   b) 10.0 gallons hypochlorite
   c) 40 lbs. hypochlorite

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY pp. 153-170.
2. Manual of Water Utility Operations, Texas Water Utilities Association, Austin, TX pp. 226-241.
3. Operation of Wastewater Treatment Plants, California Water Pollution Control Association, Environmental Protection Agency, Sacramento, CA Chapter 10.

POST-EVALUATION (10 pts. each)

1. Chlorine when mixed with water can form a substance called:
    a. "chlorine ice"
    b. "snow"
    c. crystalline hydrate
    d. liquid radicle
    e. a and c
    f. b and d
2. Chlorine gas is:
    a. explosive
    b. flammable
    c. 5 times heavier than air
    d. poisonous
3. Chlorine is used as a disinfectant. This means that:
    a. all pathogenic organisms are killed
    b. all organisms present in the water are killed
4. Which of the following statements is true?
    a. Chlorine Residual = Chlorine Demand - Chlorine Dose
    b. Chlorine Demand = Chlorine Dose - Chlorine Residual
    c. Chlorine Dose = Chlorine Residual - Chlorine Demand
5. Which of these factors do not affect chlorination?
    a. ammonia
    b. iron
    c. dissolve oxygen
    d. pH
    e. time and concentration
6. Post-chlorination means that:
    a. chlorine is added after other treatment processes
    b. chlorine is added before other treatment processes
    c. chlorine is added in excess
    d. none of the above
7. Calculate how many pounds of chlorine are needed to treat water with a chlorine demand of 10 mg./l., when a chlorine residual of 2 mg./l. is desired. The flow is 1 MGD.
8. A chlorinator is set to feed 50 lbs. of chlorine per 24 hours to a flow of 0.85 MGD. After 30 minutes of contact the residual chlorine is measured at 0.5 mg./l. What is the chlorine dosage and chlorine demand in mg./l.?
9. Chlorine gas is:
    a. blue
    b. greenish-yellow
    c. red
10. The reaction of chlorine and ammonia produces a compound which is called:
    a. Hydrazine
    b. Chloramine
    c. Ammonium chloride
    d. Chloral hydrate

ANSWERS

1. e
2. d
3. a
4. b
5. c
6. a
7. 100 lbs.
8. a) Chlorine dosage = 7.1 mg./l.
   b) Chlorine demand = 6.6 mg./l.
9. b
10. b

MODULE 8

SELF-INSTRUCTIONAL
Paul Hummel - NMSU

PLANT OPERATIONS

PREERQUISITES: Module Two - Basic Chemistry
Module Four - Microbiology
Module Seven - Chlorination

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION (5 pts. each)

1. Ground water is usually characterized by:
   a. varying mineral content and temperature
   b. clear water and few bacteria
   c. no iron or hydrogen sulfide
   d. none of the above

2. Pretreatment may be used to control:
   a. Carbonate hardness
   b. Taste and odor problems
   c. Iron and manganese problems
   d. b and c
   e. a and b

3. Coagulation is not affected by:
   a. pH
   b. turbidity
   c. temperature
   d. noncarbonate hardness

4. The most commonly used filter media for filtration is:
   a. diatomaceous earth
   b. cloth
   c. sand
   d. greensand

5. Carbonate hardness is caused by:
   a. bicarbonate salts
   b. sulfate salts
   c. chloride salts
   d. nitrate salts

6. True or False
   a. Algae can be controlled by copper sulfate and potassium permanganate.
   b. Solid particles precipitated out of solution during coagulation is called floc.
   c. Fine filter sand should be used to filter waters of low turbidity and bacterial counts.
   d. A sudden loss of head in rapid sand filters indicates that a break or crack has appeared in the sand bed.
   e. Inspection of the filtering material in pressure filters is easily done.
   f. If laboratory tests show that the total alkalinity equals the total hardness, then the calcium and magnesium bicarbonates and carbonates are producing all the hardness.
   g. Quick lime is safe to handle and requires only dry feeders.
   h. Magnesium noncarbonated hardness is removed by using lime only in the softening process.
   i. Recarbonation and complex phosphates are used to stabilize water after softening.
   j. Lime-soda ash softening gives zero hardness.

7. Column A contains five water treatment processes. Column B lists some contaminants of water. Please indicate in column A which contaminant each process could control.

A		B
Coagulation	a.	turbidity
Softening	b.	taste and odor
Aeration	c.	bacteria
Chlorination	d.	hydrogen sulfide
Pretreatment	e.	iron

ANSWERS

1. b
2. d
3. d
4. c
5. a
6. a. T
   b. T
   c. T
   d. T
   e. F
   f. T
   g. F
   h. T
   i. T
   j. F
7. Coagulation: a, c, e
   Softening: b, c, e
   Aeration: b, d, e
   Chlorination: b, c, d
   Pretreatment: a, b, c, d, e

INTRODUCTION

A good water treatment operator prepares water that is safe for consumption, looks good and is safe for property. In order to meet these objectives, knowledge of what type of contaminants are found in water and how to regulate the level of these impurities is necessary. This module will deal with the removal or regulation of aquatic contaminants.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the basics of the following concepts:

1. Pretreatment
2. Coagulation
3. Sedimentation
4. Filtration
5. Softening
6. Aeration
7. Flouridation

Mastery of this module will be shown by answering of the questions found in the Post-Evaluation with 70% accuracy.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you can understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

WATER QUALITY

Most supplies of water need to be treated before utilization. The treatment can be a one-step operation involving only one type of treatment such as chlorination or it can be a multi-step process using a series of different types of treatment. The type of treatment and number of steps needed to make water useable depends on the water source, season of the year, chemical factors and how the water is to be used.

The process utilized to treat ground water and surface water will be different. These two sources have in some respects different characteristics. For example, ground water or water drawn from wells, springs or any other underground source will reflect the type of soil or rock formations it passes through. This source usually yields clearer water with fewer bacteria. The mineral content and temperature are usually more uniform than surface water sources. Thus, in treating ground water sources, one is less concerned with turbidity (muddiness of the water) than the other source type. One also does not have to worry about varying mineral content and temperature which will affect the amount and kinds of chemicals needed for treatment. On the other hand, iron, manganese and hydrogen sulfide hardness are present in many ground supplies. Thus, an operator who treats this type of water must be aware of the amount of these contaminants present and any other mineral contaminants and use the proper procedures for reducing their concentration.

Surface water sources (lakes, reservoirs and streams),on the other hand, can be contaminated by materials contributed by the weather and pollution as well as by the geological formations it passes through. Mud, leaves, decayed vegetation and refuse will make this source unclean in appearance (or turbid). This turbidity will not always be constant from day to day. For example, heavy rains will make most surface sources extremely muddy and low in mineral content. Yet, during dry spells, the water may be relatively clear and more highly mineralized. Surface water may also be contaminated by industrial wastes which may make the water too acid, corrosive or impart a bad taste or odor to the water. Finally, surface sources are subjected to human waste more readily than ground sources (ground sources can be contaminated by feces and urine, too.)

Thus these waters may cause typhoid fever and dysentery. Surface water may also be highly mineralized and hard. Taking all this into account, the water treatment plant operator must be constantly on his toes in knowing the kind and levels of contamination found in surface water. Thus the treatment of surface water may be more complex than the treatment of ground sources.

SELF-TEST

1. __________ water is usually clearer with less bacteria present than __________ water.	ground, surface
2. Heavy rains will make surface water __________ in mineral content and __________ in turbidity.	low, high
3. Industrial wastes may make water: 1. __________ __________ 2. __________ 3. __________ and __________	too acid corrosive taste, smell bad

PRETREATMENT

Before treating water in your water treatment plant it may be necessary to pretreat the water at its source or immediately after it leaves the source. This is especially true of surface water. These waters often are high in turbidity (suspended solids) and may have odor and color problems. These problems can in many cases be controlled by pretreatment processes.

Surface sources such as rivers or lakes often have a large amount of debris such as logs or leaves. Where this problem exists it is necessary to remove this debris by means of screens. These screens should be located at the intake structure and a means to remove an accumulation of these materials should be designed so that this debris is not returned to the screen.

A common problem that plagues plants which draw their water from lakes and reservoirs is the turnover of these sources. This turnover will usually occur in the spring and fall when the weather changes. While the details of why this phenomenon occurs is beyond the scope of this module, (see Surface Water Module for more details) the problems associated with it are not. Often a gas called hydrogen sulfide is formed. This gas which smells like rotten eggs creates a taste and odor problems in the water. Any iron and manganese present in the surface supply will dissolve and get into the water distribution system. These minerals will then precipitate (become solids again). When this happens a color problem will develop and if enough of these minerals are present, a taste problem. These minerals will also stain plumbing and laundry. The conditions in the lakes and reservoirs at this time may cause the pH of the water to decrease while the concentration of carbon dioxide may increase. This in turn will impair the effectiveness of the plant.

The problems associated with turnover can be solved either by eliminating the problem at the reservoir or by more intensive water treatment. One of the ways of treating the reservoir is by oxygenating the water. Details of this method as well as other methods can be found in Manual of Water Utility Operations. For most plants these methods may not be available so the only recourse is to step up treatment at the occurance of the phenomenon.

Minerals are not the only substances that can cause taste and odor problems. Algae can also cause these problems. One way to effectively deal with algae is by means of pretreatment of the water source. Copper sulfate and potassium permanganate are the chemicals used to reduce the number of organisms in the reservoir. Copper sulfate is added in concentrations of about 0.1 to 0.5 ppm. In many cases it is only necessary to add this chemical to the shoreline where the algae growth is the greatest. Be careful though that you do not use an overdose of this chemical because it will kill fish at higher dosages. For most fish a dosage of 0.5 ppm is safe. Potassium permanganate is used to a lesser extent because of the higher dosage used and the higher cost. Dosages of this chemical needed are 0.5 to 2.0 ppm.

Taste and odor problems can also be caused by industrial and domestic sewage. The problems from these sources can be controlled either by eliminating the source or by treating the results. The elimination of a pollution source is a regulatory agency problem. Treating the results can be accomplished by aeration, chlorination, activated carbon, chlorine dioxide or by pretreating the source (as described by previous paragraphs).

SELF-TEST

1. Common problems which plague plant operators in the fall and spring are caused by lake __________.	turnover
2. Algae can cause __________ and __________ problems.	taste, odor
3. These organisms can be controlled by the use of __________ __________ or __________ __________.	copper sulfate potassium permanganate

SEDIMENTATION AND COAGULATION

Materials suspended in water, if heavy enough, will settle out. Lighter, smaller particles will settle out slower than the larger particles or not at all. The process of coagulation is a means to cause these lighter particles to stick to each other so that they are comparitively easy to remove. This process is due to the addition of certain chemicals to the water.

Coagulation consists of several steps. First, chemicals are added to the water. These chemicals are then mixed with the water so that they are evenly distributed. During mixing, solid particles begin to appear. These are caused by chemical reactions taking place between the chemicals and impurities in the water. The solid particles are called floc. The first floc particles are often small so it is necessary to gently agitate the water for a period of time. This causes the small particles to stick to each other to make larger floc. This process is called flocculation. Immediately following flocculation is a process called sedimentation. Here, the large floc particles are removed in settling basins.

There are several chemicals which can be used in coagulation. These can be used separately or in combination. Which ones or combinations of ones will depend on the characteristics of the waters to be treated.

Aluminum sulfate (alum) is the most common coagulant used. Sodium aluminate is used when a higher alkalinity is necessary for the best coagulation. Iron salts such as ferric sulfate, ferric chloride, ferrous sulfate (copperas) and chlorinated copperas are also often used when the pH is too high.

Coagulant aids by themselves do not produce coagulation. They are used with other chemicals to improve coagulation results. Some of the coagulant aids such as sodium carbonate (soda ash), sodium hydroxide (caustic soda or lye) and sulfuric acid are added to adjust the pH for best coagulation. Others, such as some clays (kaolinite and bentonite), sodium silicate and activated silica provides a surface on which the first floc can form. Artificial coagulant aids (synthetic polymers and synthetic polyelectrolyes) are used to help bring the finer particles together.

Coagulation can be affected by several factors. These include pH, salt concentrations, turbidity, type of coagulant, temperature and mixing. One of the ways to take into account all of these variables to find the proper dosage is to use the jar test. In this test, a known amount of coagulant is added in various concentrations to jars of the water to be treated. These jars are mixed uniformly for a given amount of time. The quality and settling characteristics of the floc is then observed to see which dosage gives the best results. Alum normally will produce the best coagulation at dosages from 10 to 50 ppm at a pH of 6.0 to 7.8.

Some plants use a double coagulation method. Primary coagulation to remove most of the suspended solids and to soften the water, then secondary coagulation to remove the finer suspended solids.

SEDIMENTATION

The next step in treating water after coagulation is sedimentation. Here, the floc is removed prior to filtering.

Sedimentation is accomplished by passing floc ladened water through settling tanks at a very slow velocity. This allows the larger particles to settle out. The movement through the settling tanks is generally recommended to be less than three feet per minute velocity with a detention time of six to eight hours.

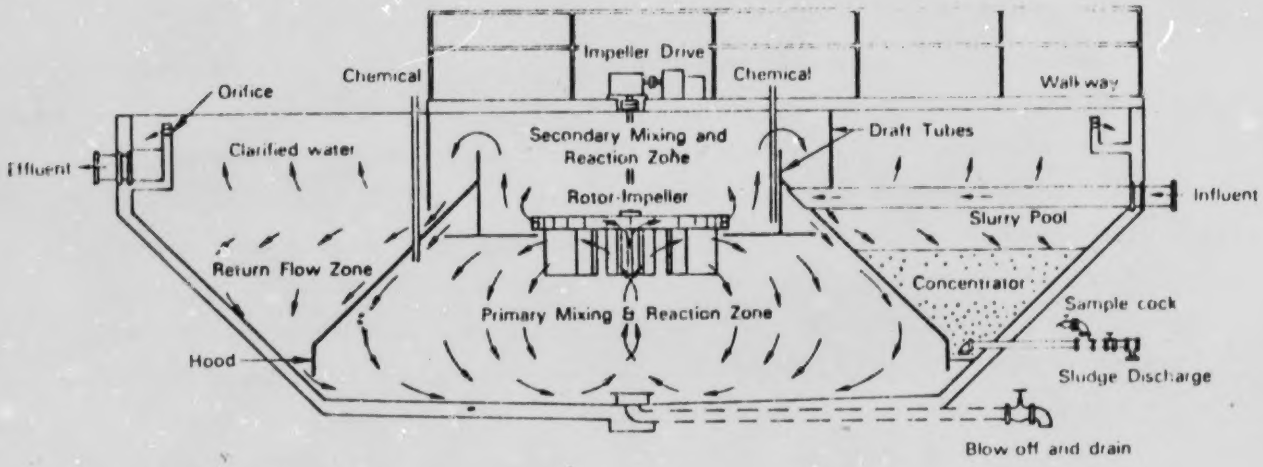
Settling tanks may be cleaned by first draining out all the water and then removing the accumulated materials from the bottom by means of squeegies and fire hoses. Modern tanks have an arm built into the bottom of the tank which rotates slowly causing the material to accumulate near the center. The material can then be drained through an opening in the bottom of the tank. These circular modern tanks are a more efficient operation in that they reduce the number of man hours needed to service the settling tanks as well as reducing the time the tanks are out of operation for servicing. Modern tanks can be cleaned without the need of drawing down the water.

There are also units in existance today which combine the coagulation and sedimentation processes. These units utilize three areas of compartments for the treatment. On the lowest level, coagulated water is added. This water is then forced upward to an area where it meets raw water entering the top of one side of the tank. The previously formed floc then provides a base for the precipitation of insoluble materials in the raw water. The rising water's upward rate is controlled so that it is slower than the settling out of the floc. Thus, the floc remains suspended in the middle of the chamber and the clear water rises above the floc to be drawn off near the top opposite the intake chamber. Figure 1 shows a type of unit used in this solids-contact process.

FIGURE 1

Solids Contact Unit

(Taken from New York Manual p. 125)


Impeller Drive
Chemical
Chemical
Walk way
Orifice
Effluent
Clarified water
Secondary Mixing and Reaction Zone
Rotor-Impeller
Draft Tubes
Influent
Slurry Pool
Return Flow Zone
Concentrator
Primary Mixing & Reaction Zone
Sample cock
Hood
Sludge Discharge
Blow off and drain

3

SELF-TEST

1. Solid particles produced during coagulation are called __________.	floc
2. __________ salts are often used when conditions are too acid to use alum.	Iron
3. To find the proper dosage of chemicals in coagulation one often uses the __________ __________.	jar test
4. Units which combine coagulation and sedimentation into one are called __________ __________ units.	solid contact

FILTRATION

Filtration is the process in which fine organic and inorganic matter is removed from the water. This is done by passing it through a suitable medium. The end product is a sparkling clear water.

While any one of several types of filtering media may be used such an anthracite, diatomaceous earth or cloth, the most commonly used is sand. These media must be hard, durable, free of impurities, insoluble in water and have good filtration characteristics. It can not be too fine because while it is very efficient in removing suspended solids, the filter run will be shortened. A courser material will lengthen a filter run but will not be as efficient in removing suspended solids.

The filtering process is accomplished on these media through the straining of the suspended matter. Large particles are caught first since they are larger than the openings between the media particles. The accumulation of these particles forms a mat which catches more and more of the finer particles. Eventually the mat becomes so thick that it impedes the flow of water through the filter. A loss of head results. When this loss of head becomes great enough the filter medium must be cleaned.

TYPES OF FILTERS

Filters may be gravity or pressure types. Of the gravity filters there are two types: the rapid or slow sand filters. Pressure filters using sand or diatomaceus earth are usually used in small communities while the gravity filters are used to treat large quantities of water.*

Slow sand filtration receives its name from the relatively slow rate it filters water. They filter 5 mgd per acre of sand bed. These type of filters consist of a covered concrete basin 10 or 12 feet deep. On the bottom of this tank tile drains are laid to connect with a central drain. On top of these drains 12 to 18 inches of graded gravel (from 2 inches to 1/8 inch) is laid with the largest on the bottom. The gravel is then covered with three feet of sand.

---

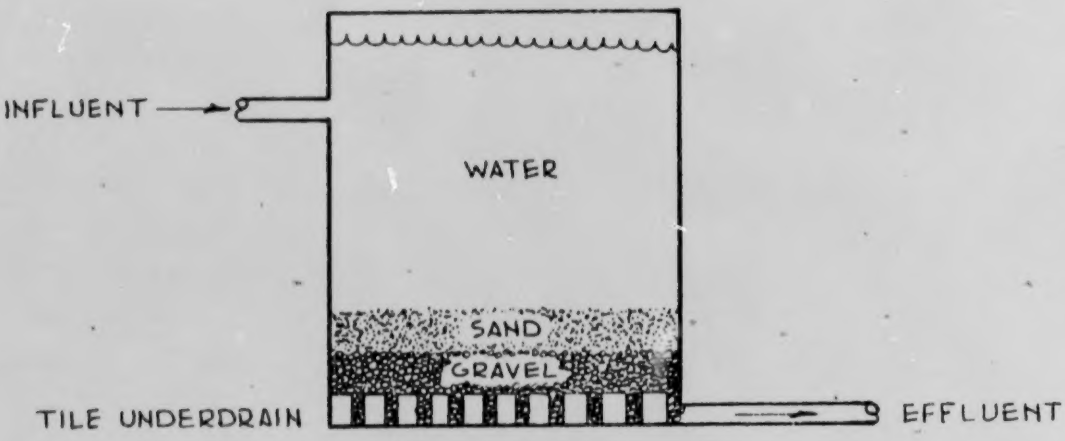
*The State of Missouri does not allow the use of pressure filters for treatment of raw water.

In order to clean these filters, water is removed from the tank and the top few inches of sand is removed. Sand can be removed several times for cleaning before any sand is replaced, but the sand bed itself must never be less than 24 to 30 inches.

This type of filter, while effective in providing a safe potable water supply, is slow. Also several days are required for the necessary build up of the mat on the filter bed itself. This means that during this time the water cannot be used. Figure 2 shows a "typical" slow sand filter.

FIGURE 2

Slow Sand Filter



Gravity, rapid sand filters, or mechanical sand filters are often used in larger communities where rapid processing of large quantities of water is necessary (Figure 3)· This type of filter has a rate of filtration about forty times the rate of filtration through slow sand filters. The term mechanical used to describe this type of filter comes from the fact that mechanical washing equipment is used to clean the beds.

The filter unit is made up of a tank or box which contain the filter media and underdrains. The box or tank can be any shape or size. It is usually built of concrete. In this box or tank the filter media is placed. The media usually consists of silica sand and gravel. Some treatment plants today are using crushed anthracite coal to replace the filtering sand or are using multimedia filters which combine sand and anthracite. Whichever media is used, a series of layers of graded gravel is first layed in the box. The coarsest layer of gravel being put on the bottom. On top of the gravel a 24-30 inch layer of graded washed filter sand or anthracite is placed.

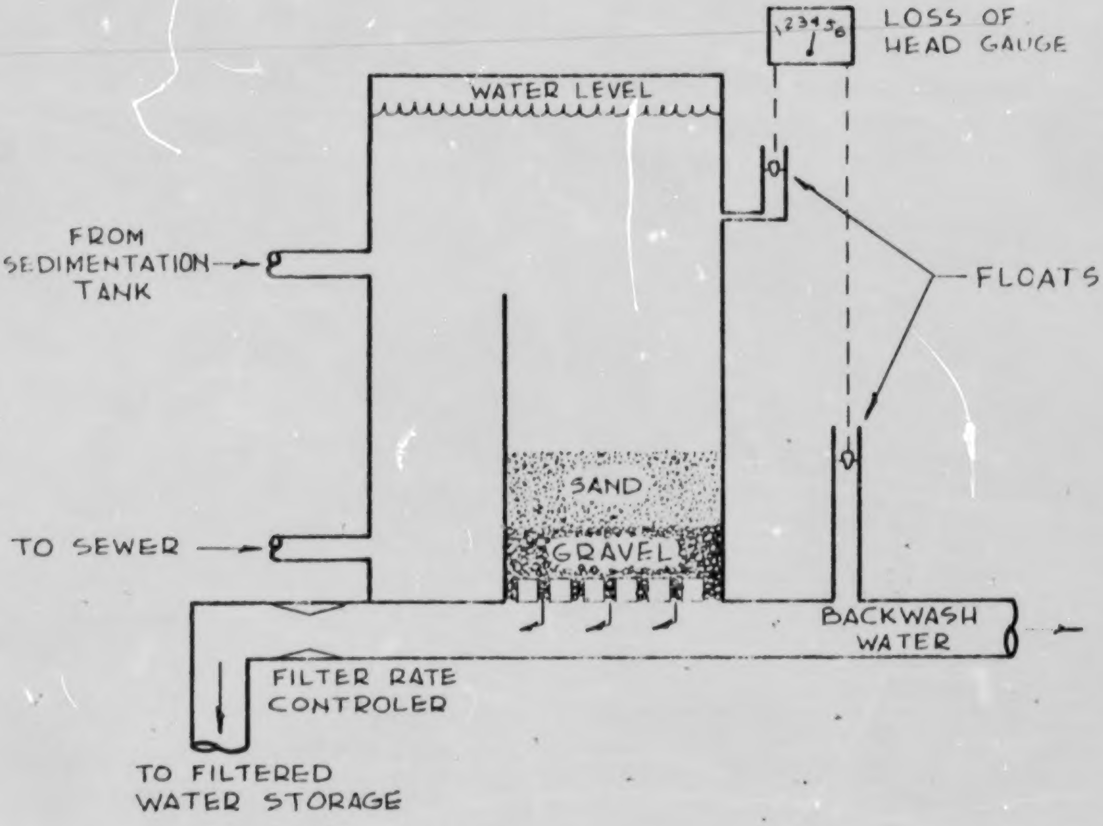
The filter sand used should be free of dirt and clay. It will have an effective size range of 0.4 to 0.50 millimeters and a uniformity coefficient of not more than 1.65. The term effective size refers to the size of grain in a sample. Uniformity coefficient is a term refering to the size of a sieve through which 10% of the sand can pass. If coagulation and sedimentation are poor, then finer sand may be needed. The coarser the sand the longer the run. This is because coarser sand permits deeper penetration of suspended materials.

Anthracite coal used as a filter media offer some advantages over sand filter media. When using this media, the filter runs are longer and half the back wash velocity of a comparable sand media is needed. Anthracite will not coat as extensively as the coat build up on sand and it is not soluble in acid or alkali.

Under the filter media is a filter bottom composed of ceramic tiles or aluminum oxide porous plates. Some filter bottoms are concrete with pyramidal depressions containing a graded series of ceramic balls (3" to 1 1/4"). The purpose of these special bottoms is to collect the filtered water and to uniformly distribute the relatively large flow of wash water.

FIGURE 3

Rapid Sand Filter


123456
LOSS OF HEAD GAUGE
WATER LEVEL
FROM SEDIMENTATION TANK
FLOATS
SAND
GRAVEL
TO SEWER
BACKWASH WATER
FILTER RATE CONTROLER
TO FILTERED WATER STORAGE

The rapid sand filter operates by filtering coagulated settled water through the filter media. When the filter becomes clogged, it is washed by forcing filtered water upward through the media. This process lifts the sand and agitates it so that any material trapped in the media is loosened. This material is then gathered at the surface and is carried away in the wash water. Washing usually lasts from four to seven minutes. After which, the filter is again put in service.

Rapid sand filters are washed when a loss of head equals the distance from the water surface on the filter to the bottom of the sand layer. Head loss will naturally rise steadily throughout the filter run as an accumulation of material on the media reduces the flow of water through the filter. If a sudden loss of head is encountered, this may mean that a break or crack has appeared in the sand bed. This cracking or breaking will permit unsatisfactorily filtered water to pass through. In either case, the filter should be backwashed until the water passing through the filter is clear.

As mentioned in the previous paragraph, an increasing loss of head is encountered during a filter run. In order to overcome this loss and to keep the rate of flow through the filter constant, a mechanical device called a rate controller is used.

Filter rate controllers may operate on any number of principles. The most common type works on the Venturi Tube Principle. In these types of devices, the difference of pressures at the large and small section of a tube is measured. This difference will indicate the rate of flow through the tube. If the rate of flow is greater or less than what the controller is set for, it will automatically adjust valves to permit the proper rate of flow.

While the slow sand filter and rapid sand filter are the two most common types of filtering systems used to treat public water supplies, you should also be aware of the pressure filter and diatomaceous earth filters.

Pressure filters are essentially rapid sand filters enclosed in a steel cylindrical tank through which water is passed under great pressure. These filters can be either the vertical or horizontal types. Pressure filters can be used to remove iron from ground waters and treat recirculating swimming pool waters. They are generally less expensive to build, and are free from air binding. The disadvantage to this type of filter is that easy inspection of the filtering material is difficult. It is also difficult to observe wash water efficiently.

Diatomaceous earth filters* is also a type of pressure filter. In this filter a coating of diatomaceous earth (skeletons or microscopic animals) is held in place by water pressure on a fine screen. This screen can be made of a number of different materials such as synthetic cloth, wire cloth, non-woven materials and sintered grain. The diatomaceous earth is placed on the screen at the start of each run by adding a slurry to the filter tank. Water is then circulated through the filter to develop the pre-coat. When this is in place, the filter is placed on line. Throughout the run a prescribed amount of this media is added to the influent to lengthen the filter run. Cleaning is accomplished by backwashing the screen to remove the filter media which is discarded after every run.

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*This type of pressure filter is only allowed to be used in the treatment of swimming pool water by the State of Missouri.

This type of filter occupies little space and will produce high quality water. Its initial cost is also less than a rapid sand filter. Since coagulants will plus this filter, it is used primarily to filter water with low turbidity and microorganisms, where coagulation is not required. Thus, their use is generally restricted to small, temporary or portable installations.

While most water plants have some type of filtration, it may not be necessary in some cases. Well water supplies, for example, may find it more economical to provide longer retention periods in mixing tanks and sedimentation basins than to build filters. If these supplies are softened by the lime and soda ash process, and the reaction period and settling time is long enough, a clear water can be produced without filtration. If filters are not used, a 0.50 mg./l. dosage of a polyphosphate salt, such as sodium polyphosphate should be added to the water before it is placed in the distribution system. This will insure proper stabilization.

SOFTENING

The process of softening is used to reduce hardness. As explained in an earlier module (Chemistry, Module 2), hardness is the ability of water to produce lather from soap. If a lot of soap is needed to produce a lather, then the water is said to be hard. Hard water can also produce deposits in hot water systems.

Water hardness is caused by the presence of calcium and magnesium compounds. Iron, manganese and aluminum compounds will also cause hardness but they are often present in such small quantities that they are usually not connected with hardness.

There are two types of hardness: carbonate and noncarbonate. Calcium and magnesium bicarbonates present in water is called carbonate hardness. Noncarbonated hard waters have present sulfates of calcium and magnesium. Other compounds of these two elements such as chlorides and nitrates can also cause hardness. Fortunately, this form of noncarbonated hardness is only a minor contributor to hardness. Total hardness is measured in terms of the mg./l. (or ppm) of calcium carbonate. It is the sum of calcium hardness plus the magnesium hardness.

One can distinguish between carbonate and noncarbonate hardness in the following way:

1. If laboratory tests show that the total alkalinity equals the total hardness, then the calcium and magnesium bicarbonates and carbonates are producing all the hardness. This is called carbonate hardness.
2. When the total hardness is found to be greater than the total alkalinity, the carbonate hardness is equal to the alkalinity and the noncarbonate hardness is equal to the total hardness minus the total alkalinity.
3. Tests that show that the total hardness is less than the total alkalinity indicates that no noncarbonated hardness is present. In this case, the difference between the total hardness and the total alkalinity is the amount of sodium and potassium carbonates that are present. This situation is often referred to as negative noncarbonate hardness.

One must remember that a total hardness test does not tell what minerals cause the hardness only that the hardness is equivalent to that produced by calcium carbonate.

Removal of hardness or softening can be done by one of two methods. They are the use of lime and soda for chemical precipitation of calcium and magnesium or by a process called ion exchange. Many larger plants use the precipitation method; while smaller towns and industry use the ion exchange method.

LIME SODA AND ASH PROCESS (CHEMICAL PRECIPITATION)

This process of softening consists of six basic steps: 1. First, the water is aerated. 2. Chemicals to produce coagulation and softening are then added to the water. 3. These chemicals are mixed with the water and 4. the precipitates formed are allowed to settle. 5. Finally, the water is carbonated and 6. filtered.

The chemicals used to soften water are lime (hydrated lime $Ca(OH)_2$ or quick lime (CaO) and soda ash or caustic soda ($NaOH$). Lime is used to cause the hardness minerals to precipitate out. The form used, hydrated lime or quick lime, will depend on the cost of the lime as well as the size and equipment of the plant. Hydrated lime is fed in a dry chemical feeder in which the powdered lime is added to water to form a slurry. The lime in this slurry then becomes calcium hydroxide. This compound is also formed when quick lime is added to water. This form of lime comes in pebble or pulverized unslaked form. Therefore, quick lime must be slaked before use. Lime is fed by a dry feeder into an agitated water bath for slaking. Hydrated lime requires only dry feeders and is simple to handle. Quick lime requires both dry feeders and slakers; it is also more difficult to handle.

Lime is used for the removal of calcium and magnesium bicarbonate or carbonate hardness. The lime reacts with these compounds to form insoluble calcium carbonate and/or magnesium hydroxide. The chemical equations for these reactions are as follows: Note the vertical arrow pointed downward indicates a precipitate.

Carbon Dioxide Removal

$$CO_2 + Ca(OH)_2 = CaCO_3 \downarrow + H_2O$$

carbon dioxide + calcium hydroxide = calcium carbonate + water

Calcium Bicarbonate Removal

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2\ CaCO_3 \downarrow + 2\ H_2O$$

calcium bicarbonate + calcium hydroxide = calcium carbonate + water

Magnesium Bicarbonate Removal

$$Mg(HCO_3)_2) + 2\ Ca(OH)_2 = Mg(OH)_2 \downarrow + 2\ CaCO_3 \downarrow + 2\ H_2O$$

magnesium bicarbonate + calcium hydroxide = magnesium hydroxide + calcium carbonate + water

Noncarbonated hardness is removed by soda ash (sodium carbonate Na_2CO_3) and/or lime. Soda ash will remove calcium sulfate hardness while lime and soda ash is used on magnesium noncarbonated hardness. The reactions are as follow:

Calcium Sulfate Removal

$$CaSO_4 + Na_2CO_3 = CaCO_3 \downarrow + Na_2SO_4$$

calcium sulfate + sodium carbonate = calcium carbonate + sodium sulfate

Magnesium Sulfate Removal

$$MgSO_4 + Na_2CO_3 + Ca(OH)_3 = Mg(OH)_2 \downarrow + CaCO_3 \downarrow + NaSO_4$$

magnesium sulfate + sodium carbonate + calcium hydroxide = magnesium hydroxide + calcium carbonate + sodium sulfate

When softening water, it is important to determine the pH. A pH of 9.5 is needed for the precipitation of calcium carbonate while a pH of 10.5 is the needed for the precipitation of magnesium hydroxide. Therefore in order to remove magnesium the pH must be raised. This is done by adding an excess amount of lime to the untreated water. This will ensure a maximum formation of precipitation. Often when the water is softened the left over lime must be neutralized before it can be put in the distribution system. The neutralization can be done by adding soda ash or treating with carbon dioxide. The first process is called the split lime treatment. The addition of carbon dioxide is called recarbonation. The use of these treatments prevent the future precipitation of calcium carbonate which may not have precipitated out in the softening process.

Additional soda ash, recarbonation and the addition of complex phosphates produces stabilized water. (Stable water is one that will not deposit calcium carbonate or dissolve calcium carbonate.) The effects of excess soda ash and recarbonation has already been explained. Complex phosphates help stabilize water by retaining chemicals in solution. Dosages of these phosphates will vary from 0.5 to 5.0 mg/l. and can be applied before or after filtration.

Another chemical which is added to water to promote softening is alum or aluminum compounds and iron compounds. This compound reduces the amount of time needed for the reaction to take place. In other words, alum and iron compounds decreases the time it takes for the insoluble compounds to settle out.

The advantage to using the lime and soda ash treatment is found not only in its ability to soften the water but also in the removal of iron and manganese, reduction in the amount of total solids in the water, control of corrosion or scale formation and reduction of the dissolved silica and flouride content of the water. The higher pH during treatment will produce some disinfection. Some taste and odor problems may be reduced. There are also some disadvantages to this softening method. For example, color removal may become difficult because of higher pH values. Sludge disposal must be done to control the cost of the chemicals used. Figure 4 gives an example flow diagram of a treatment plant using lime softening to remove magnesium and calcium hardness.

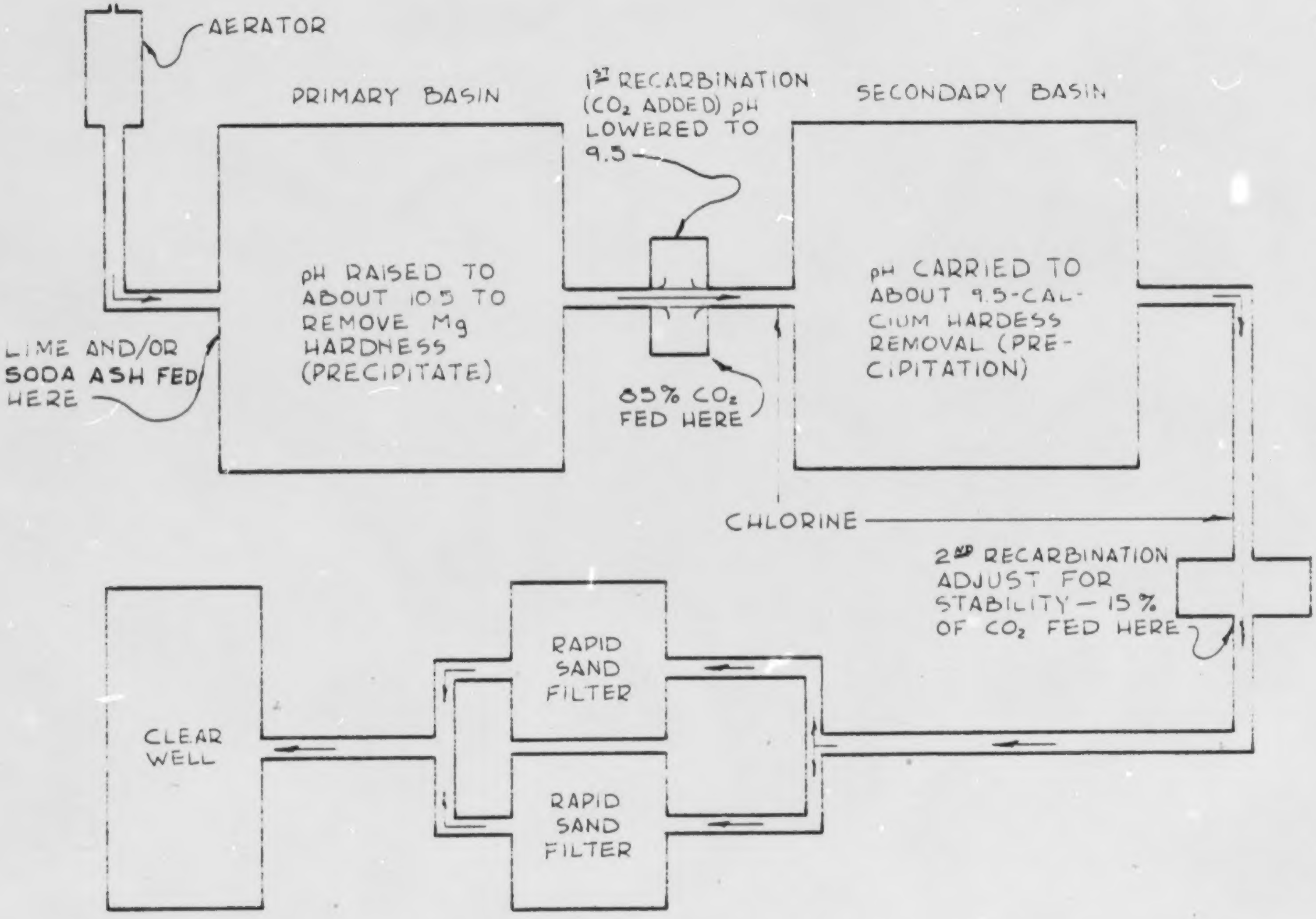

AERATOR
PRIMARY BASIN
1ST RECARBINATION (CO2 ADDED) pH LOWERED TO 9.5
SECONDARY BASIN
pH RAISED TO ABOUT 10.5 TO REMOVE Mg HARDNESS (PRECIPITATE)
LIME AND/OR SODA ASH FED HERE
85% CO2 FED HERE
pH CARRIED TO ABOUT 9.5-CALCIUM HARDESS REMOVAL (PRECIPITATION)
CHLORINE
2ND RECARBINATION ADJUST FOR STABILITY — 15% OF CO2 FED HERE
CLEAR WELL
RAPID SAND FILTER
RAPID SAND FILTER

FIGURE 4

Lime Softening

ION EXCHANGE (ZEOLITE PROCESS)

While soda ash-lime treatment can not give zero hardness, a process called ion exchange can. Softening by ion exchange works by removing calcium and magnesium ions and replacing them by some other ions such as sodium. This process will produce water of zero hardness as long as there are enough replacement ions present to take the hardness causing ions place. When the exchange ions are depleted, the exchange bed is recharged by passing a strong solution of sodium chloride through it. The sodium ions will then take the place of the calcium and magnesium ions deposited on the bed. After recharging the exchange bed can be again used for softening.

Ion exchange materials can be made of natural greensands, processed greensands, synthetic gels or sulfonate coal. Most modern plants however use synthetic resins. This media is more efficient, has a longer life and has a higher capacity.

SELF-TEST

1. Filter sand should have an effective size range of __________ to __________mm.	0.4 to 0.5
2. The chemicals used to soften water are __________or __________ __________.	lime, soda ash
3. __________will remove carbon dioxide and carbonate hardness.	lime
4. A pH of __________is maximum for the precipitation of calcium carbonate.	9.5
5. __________ __________ is one that will not deposit calcium carbonate or dissolve calcium carbonate.	stable water
6. The Zeclite Process works by exchanging __________ for calcium and magnesium ions.	sodium

CHLORINATION

In order to insure that drinking water is free of pathogenic bacteria, chlorine or chlorine compounds are added to water to disinfect it. This disinfectant is added in such quantities so that the chlorine demand is satisfied. Then an excess is added so that some free residual chlorine is allowed in the distribution system. This free residual chlorine is often produced by a process called "breakpoint" chlorination.

"Breakpoint" chlorination can be explained as follows. As chlorine is added to water, the amount of residual chlorine increases to a point. At this point additional chlorine will only decrease the amount of residual present. In "breakpoint" chlorination, chlorine is continually added even after the decrease in residual chlorine is observed. If enough chlorine is added, the residuals will again start to increase. The start of this second residual increase is called the "breakpoint". At this point taste and odor problems are at a minimum. This process as well as the other details involved in the chlorination process are explained in Module 7, Chlorination.

FLUORIDATION

In order to prevent tooth decay, fluorine compounds are added to the water. The most commonly used fluorine compounds used are sodium fluoride (NaF), sodium silicofluoride (Na_2SiF_6), ammonium silicofluoride ($(NH_4)_2SiF_6$), fluosilicic acid (H_2SiF_6) and calcium fluoride (CaF_2). These chemicals can be applied in dry form, in solution or as a slurry.

Fluoridation practices can create some problems for the operator. For example, a buildup of insoluble deposits may form in feedline piping and equipment. These deposits come from the use of calcium fluoride mixed with hard water. Use of ion-exchange filters can solve this problem. Corrosion problems may also be encountered when fluosilicic acid or sodium silicofluoride solution are used, therefore plastic pipes should be used.

Flourine in concentrations of 1 ppm in water supplies has been found to significantly decrease the amount of tooth decay present in the population. If flourine is added to the water in greater amounts such as 3 to 4 ppm over a long period of time, the consumers will begin to have mottled (or stained) teeth. This phenomonon will have no harmful effects on the population.

AERATION

Aeration is used in the treatment plant to remove the gases which have offensive tastes and odors or affect the treatment process. It may remove some dissolved minerals such as iron and manganese. Oxygen is also added to the water in this process.

Gases such as hydrogen sulfide, carbon dioxide, methane and some volatile organic compounds are often released as the water comes in contact with the air. Hydrogen sulfide which creates taste, odor and corrosion problems will be effectively removed if the pH of the water is not high. If the pH is too high, chlorination should be substituted for this process. Carbon dioxide may be corrosive and interfere with the softening process if not removed by aeration.

Some minerals such as iron and manganese are caused to precipitate when in contact with the air. This precipitate can then be removed by filtration. More effective means of removing these minerals though, is by softening or chlorination.

Aeration can be done in various ways. Water can be allowed to flow over cascades or steps. It can be sprayed from a nozzle, by trickling through trays of coke or by forced or induced draft aerators.

PLANT SYSTEMS

This module has so far explained the various treatment processes. It has told why and how the processes are used and some of their advantages and disadvantages. Let us now see how these treatment operations are used to produce potable water. All figures given on the next page and figure 4 were provided courtesy of Mr. Don Sisson, Department of Natural Resources. Figure 10 was provided by Mr. Gene Bennet of the Chillicothe Treatment Plant.

Ground Water Supplies

When chlorination is used alone the plant flow diagram may be as follows:

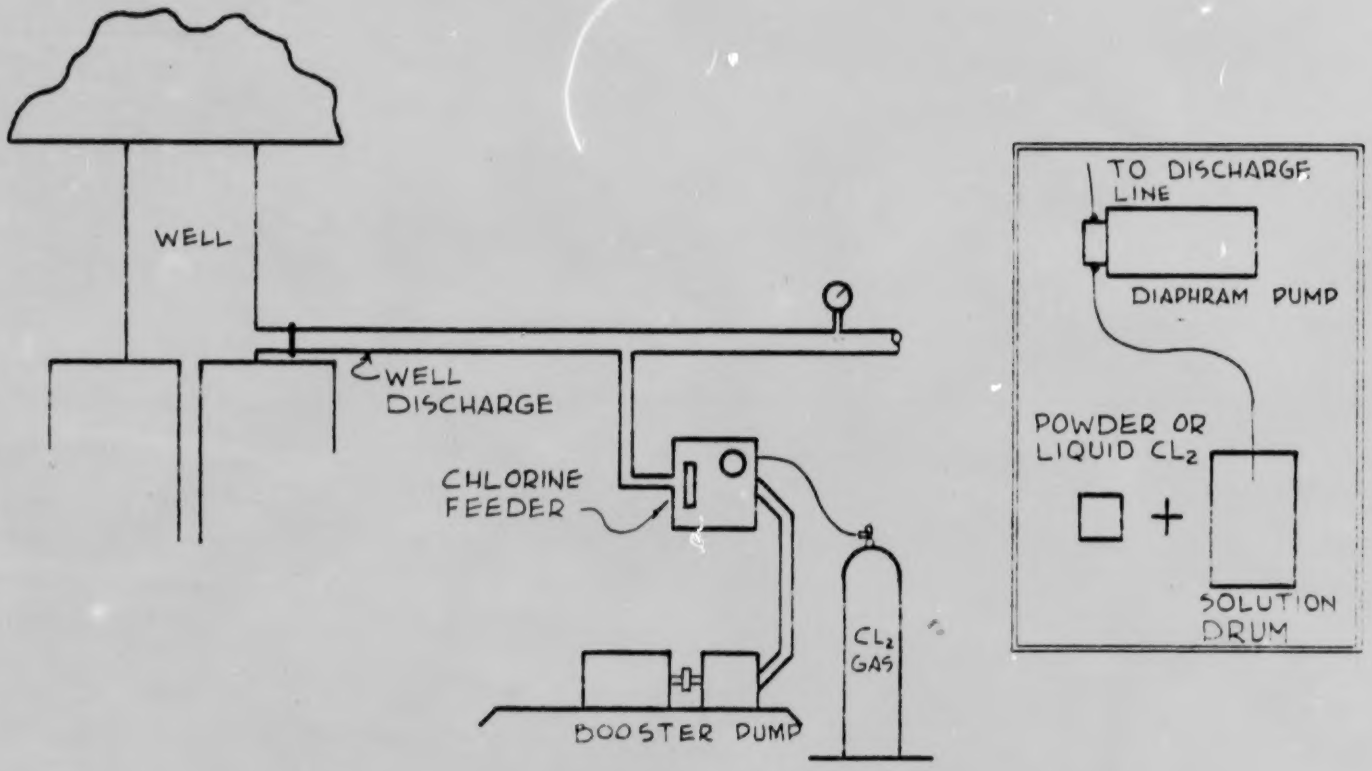

WELL
WELL DISCHARGE
CHLORINE FEEDER
BOOSTER PUMP
CL_2 GAS
TO DISCHARGE LINE
DIAPHRAM PUMP
POWDER OR LIQUID CL_2
+
SOLUTION DRUM

FIGURE 5

Ground Water Supplies Chlorination Only

For those ground supplies which contain iron, a plant may be set up as follows:

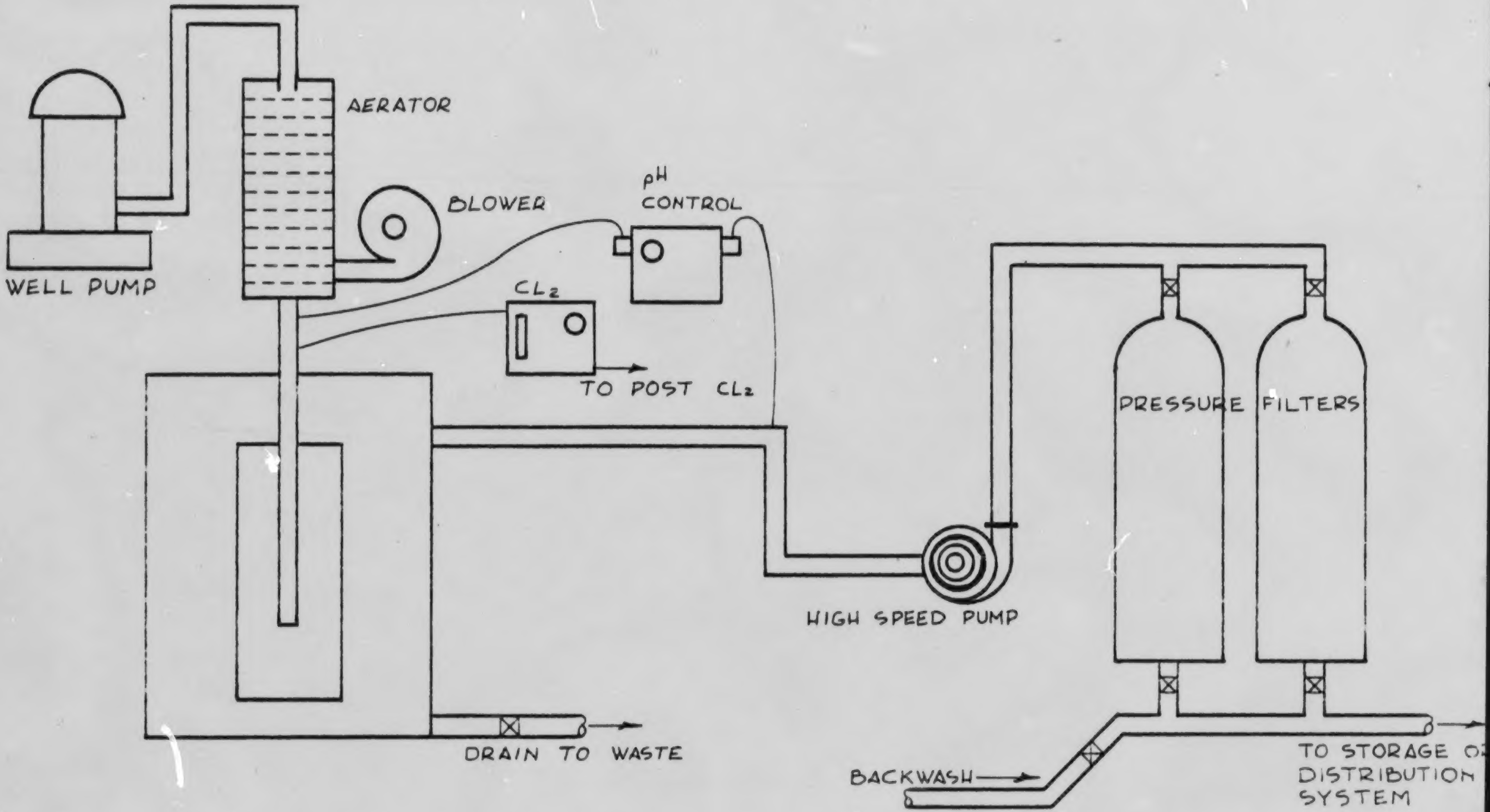

AERATOR
BLOWER
pH CONTROL
WELL PUMP
CL2
TO POST CL2
PRESSURE FILTERS
HIGH SPEED PUMP
DRAIN TO WASTE
BACKWASH
TO STORAGE O
DISTRIBUTION
SYSTEM

FIGURE 6

Ground Water Supplies Iron Removal

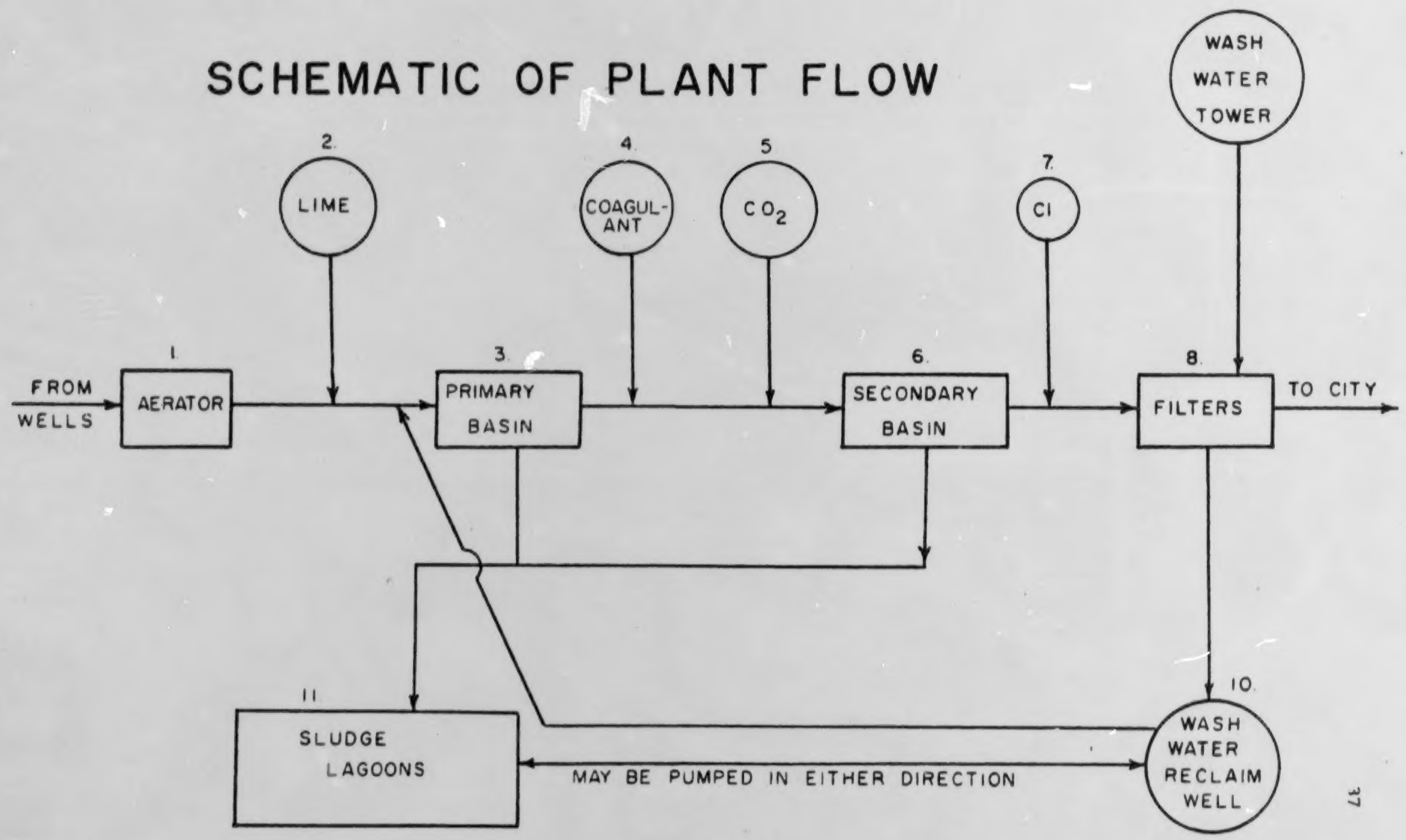

SCHEMATIC OF PLANT FLOW
FROM WELLS
1. AERATOR
2. LIME
3. PRIMARY BASIN
4. COAGULANT
5. CO2
6. SECONDARY BASIN
7. CI
8. FILTERS
TO CITY
9. WASH WATER TOWER
10. WASH WATER RECLAIM WELL
11 SLUDGE LAGOONS
MAY BE PUMPED IN EITHER DIRECTION

FIGURE 7

SCHEMATIC OF PLANT FLOW

SURFACE WATERS

An example of a general flow diagram for the treatment of surface waters is given in Figure 8. The treatment of water for Jefferson City, Chillicothe and Kansas City are represented by Figures 9, 10 and 11. All the diagrams represent only a few examples of how a plant may be designed. Raw water quality, the water source and the economics of the area the plant serves will all influence the type of treatment processes used as well as the design of the plant.

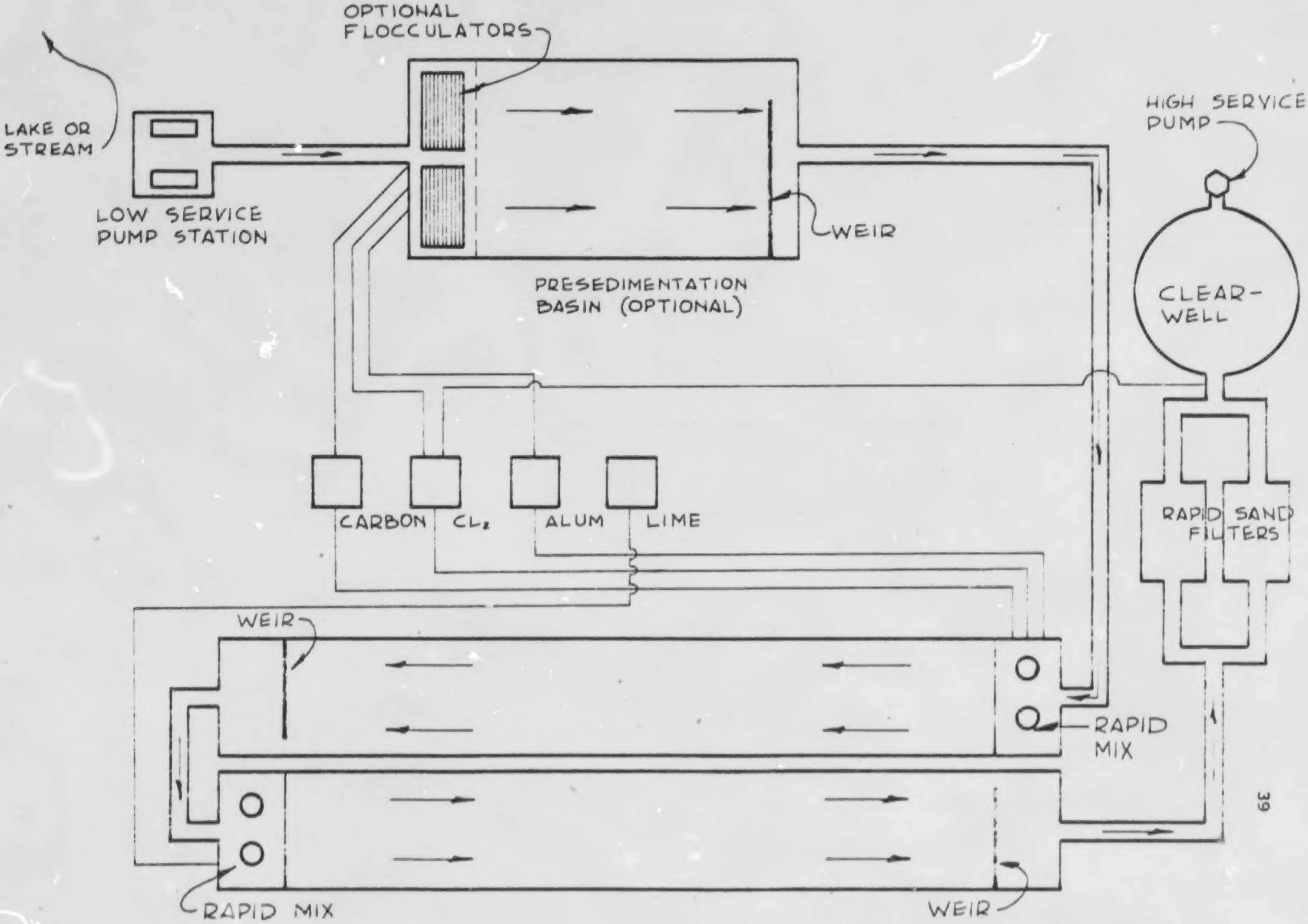

OPTIONAL FLOCCULATORS
LAKE OR STREAM
LOW SERVICE PUMP STATION
WEIR
PRESEDIMENTATION BASIN (OPTIONAL)
HIGH SERVICE PUMP
CLEAR-WELL
CARBON
CL₂
ALUM
LIME
RAPID SAND FILTERS
WEIR
RAPID MIX
RAPID MIX
WEIR

FIGURE 8

SURFACE SUPPLY

FIGURE 9
JEFFERSON CITY

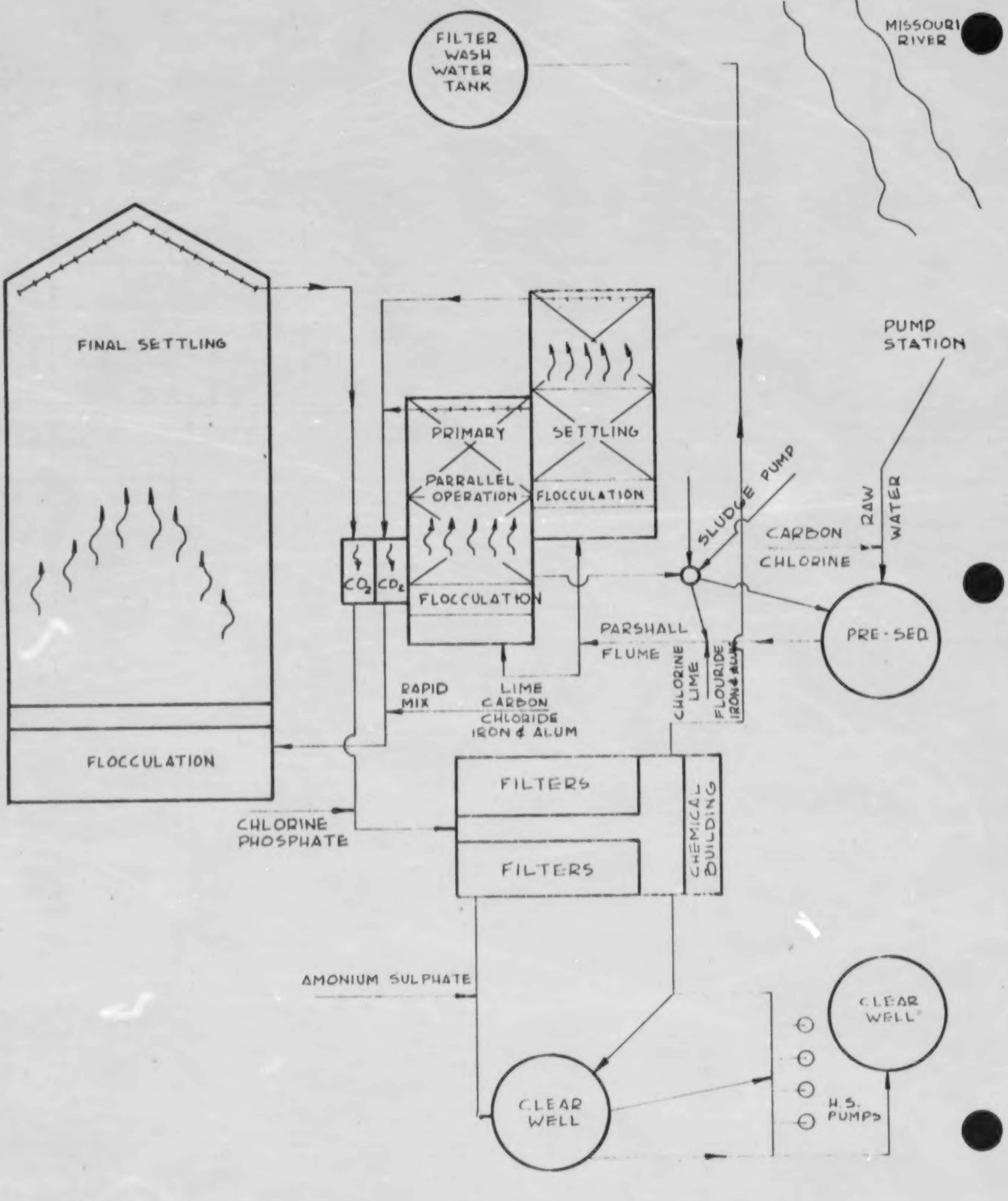
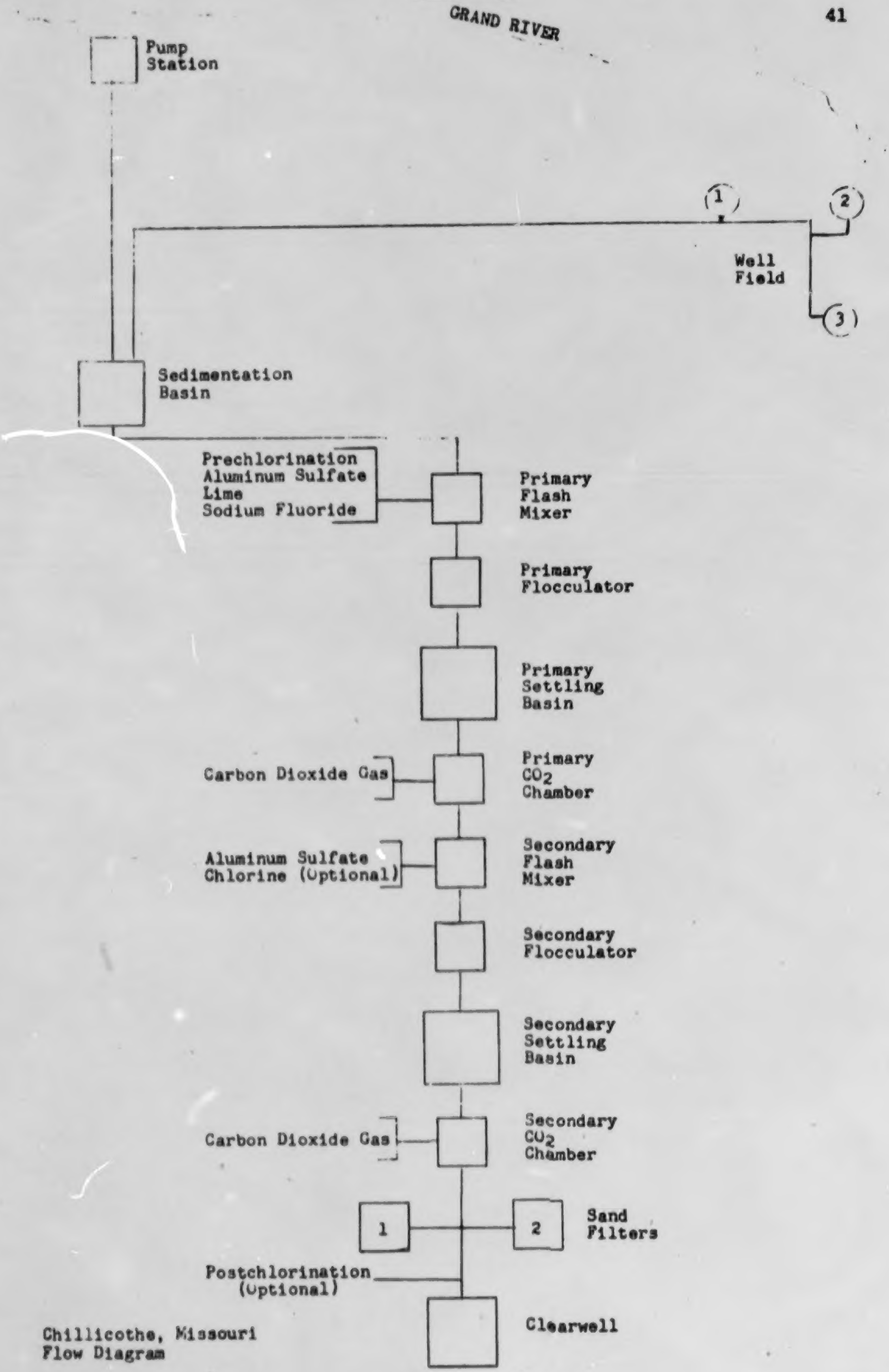

FILTER WASH WATER TANK
MISSOURI RIVER
FINAL SETTLING
PRIMARY
SETTLING
PARRALLEL OPERATION
FLOCCULATION
PUMP STATION
SLUDGE PUMP
CO_2
CO_2
FLOCCULATION
RAW WATER
CARBON
CHLORINE
PARSHALL FLUME
PRE-SED
RAPID MIX
LIME
CARBON
CHLORIDE
IRON & ALUM
CHLORINE
LIME
FLOURIDE
IRON & ALUM
FLOCCULATION
FILTERS
FILTERS
CHEMICAL BUILDING
CHLORINE
PHOSPHATE
AMONIUM SULPHATE
CLEAR WELL
CLEAR WELL
H.S. PUMPS

FIGURE 10

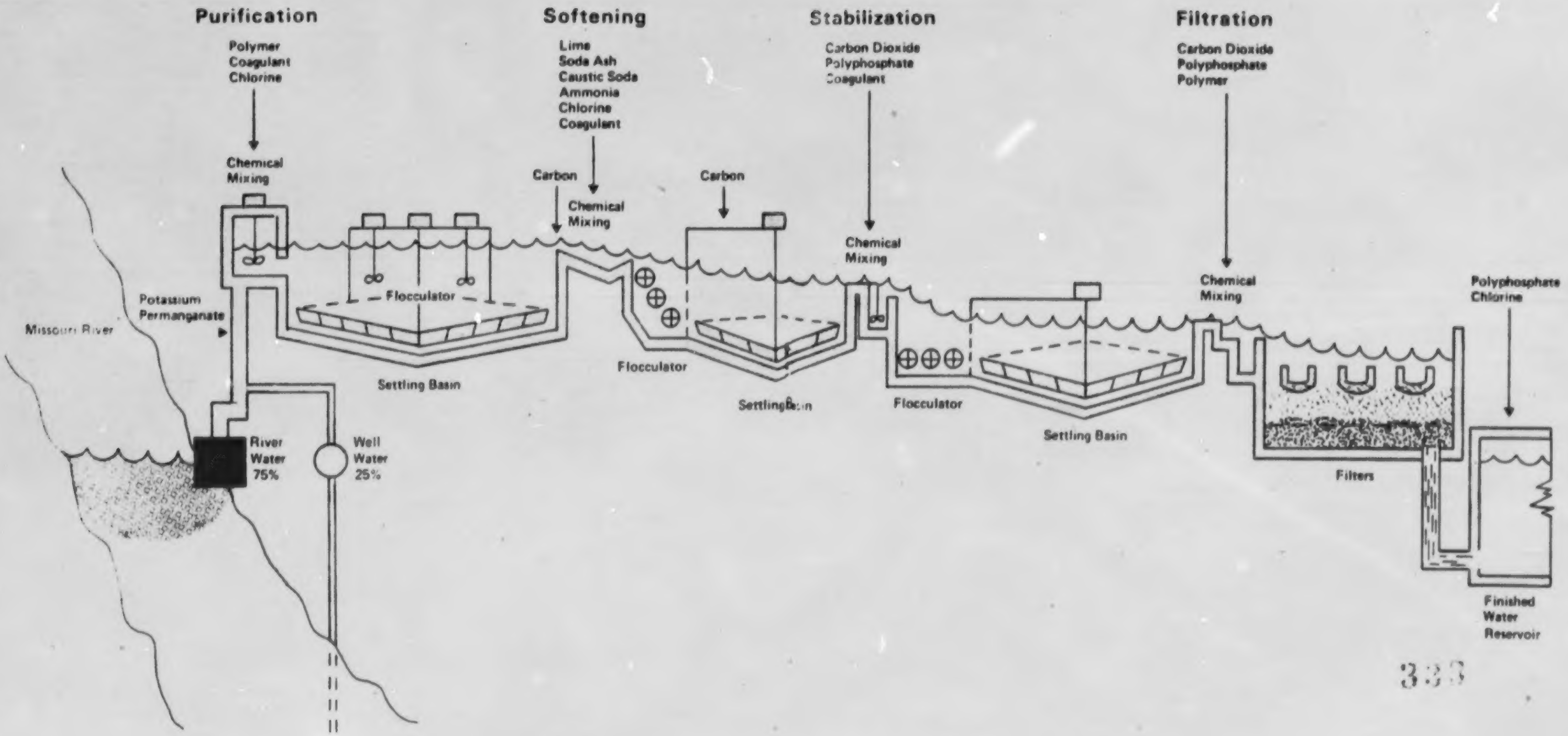

GRAND RIVER
Pump Station
1
2
3
Well Field
Sedimentation Basin
Prechlorination
Aluminum Sulfate
Lime
Sodium Fluoride
Primary Flash Mixer
Primary Flocculator
Primary Settling Basin
Carbon Dioxide Gas
Primary CO2 Chamber
Aluminum Sulfate
Chlorine (Optional)
Secondary Flash Mixer
Secondary Flocculator
Secondary Settling Basin
Carbon Dioxide Gas
Secondary CO2 Chamber
1
2
Sand Filters
Postchlorination (Optional)
Clearwell

Chillicothe, Missouri
Flow Diagram

FIGURE 11

PLANT FLOW DIAGRAM

WATER TREATMENT STAGES


Purification
Polymer
Coagulant
Chlorine
Chemical Mixing
Softening
Lime
Soda Ash
Caustic Soda
Ammonia
Chlorine
Coagulant
Carbon
Chemical Mixing
Carbon
Stabilization
Carbon Dioxide
Polyphosphate
Coagulant
Chemical Mixing
Filtration
Carbon Dioxide
Polyphosphate
Polymer
Chemical Mixing
Polyphosphate
Chlorine
Missouri River
Potassium Permanganate
Flocculator
Settling Basin
Flocculator
Settling Basin
Flocculator
Settling Basin
Filters
River Water 75%
Well Water 25%
Finished Water Reservoir

333

332

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY pp. 115-214.
2. Manual of Water Utility Operations, Texas Water Utilities Association, Austin, TX pp. 182-268.
3. Water Supply and Treatment by M. L. Riehl, National Lime Association, Washington, (1976), 224 pages.

POST-EVALUATION (5 pts. each)

1. True or False
   a. Aeration is used in water treatment to add oxygen or remove objectionable gases.
   b. In order to effectively remove hydrogen sulfide by aeration, the pH of the water must be high.
   c. Fluorine is not dangerous if treated water is overdosed with it.
   d. Fluorine compounds are usually applied to the filtered effluent.
   e. Chlorine compounds are added to water primarily to sterilize it.
   f. Free residual chlorine is often produced by a process called "breakpoint" chlorination.
   g. The Zeolite Process will produce zero hardness.
   h. Alum can be used in the softening process to reduce the amount of time needed for softening reactions to take place.
   i. For the maximum precipitation of calcium carbonate the pH of the water should be 10.5.
   j. Only soda ash is used to remove magnesium noncarbonated hardness.
   k. A total hardness test will tell what minerals cause the hardness.
   l. Total hardness is measured in terms of the ppm of calcium carbonate.
   m. Hardness is caused by the presence of calcium, magnesium, iron, manganese and aluminum compounds.
   n. The filter media in diatomaceous earth filters can be reused after every backwashing.
   o. The most common type of filter rate controllers operates on the Venturi Tube Principle.
   p. Rapid sand filters are washed when the increase in head equals the distance from the water's surface on the filter to the bottom of the sand layer.
   q. Rapid sand filters have a rate of filtration equal to about forty times the rate of filtration of slow sand filters.
   r. Alum works best at pH of 4.0 to 6.0.
   s. The next step after flocculation in the coagulation process is filtration.
   t. Turn over of lakes and reservoirs cause no problems for water treatment plant operators.

ANSWERS

1. a. T
   b. F
   c. F
   d. T
   e. F
   f. T
   g. T
   h. T
   i. F
   j. F
   k. F
   l. T
   m. T
   n. F
   o. T
   p. F
   q. T
   r. F
   s. F
   t. F

MODULE 9

SELF-INSTRUCTIONAL

Paul Hummel - NMSU

SURFACE WATER

PREREQUISITES: None

DIRECTIONS: Take the self-evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the self-tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. The study of the movement of water is called (20 pts.)
   a. Limnology
   b. Entomology
   c. Hydrology
   d. Hydraulics

2. Water returning to earth in the form of rain, sleet or snow is called (20 pts.)
   a. Evaporation
   b. Precipitation
   c. Condensation
   d. Humidity

3. When water reaches the earth it can (20 pts.)
   a. evaporate
   b. sink into the earth
   c. form run-off
   d. all of the above
   e. none of the above

4. One of the sources of water is surface run-off. This consists of (20 pts.)
   a. rivers
   b. lakes
   c. wells
   d. underground streams
   e. a and b
   f. c and d

5. True or false (4 pts. each)
   a. 3/4 of the public water supply in the U.S.A. comes from surface sources.
   b. Surface supplies are inexhaustable
   c. The safe yield of a watershed equals the minimum flow rate expected in the future.
   d. Water in its natural state is pure.
   e. Natural lakes and reservoirs usually need less treatment than water supplies from rivers.

ANSWERS

1. c
2. b
3. d
4. e
5. a. False
    b. False
    c. True
    d. False
    e. True

INTRODUCTION

Hydrology is the study of water's movement on, in and above the earth. In this module you will discover how water is distributed and why it is where it is. You will also see how impurities enter the water cycle and why it is important to know the run-off characteristics of your water supply's watershed.

PERFORMANCE OBJECTIVE

When this module is complete, you will be able to show that you have mastered the following concepts:

1. Hydrological cycle
2. Water sources
3. Quality of water sources

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if you answer it correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

HYDROLOGICAL CYCLE

Oceans cover 71% of the earth's surface and contain 97% of the earth's total supply of water. The other 3% is fresh water found in the atmosphere as precipitation, on the land in lakes and streams and underground in deep aquifers (layers of rocks, sands or gravel). Of all the fresh water, 75% is stored in the polar ice caps and glaciers. The rest is found below the surface. Only 1/3 of 1% of the fresh water is found in lakes and rivers.

Sometimes water will move freely from one point to another. At other times it may be locked up for thousands of years such as the water found in ice caps and glaciers. The study of the movement of water is called hydrology.

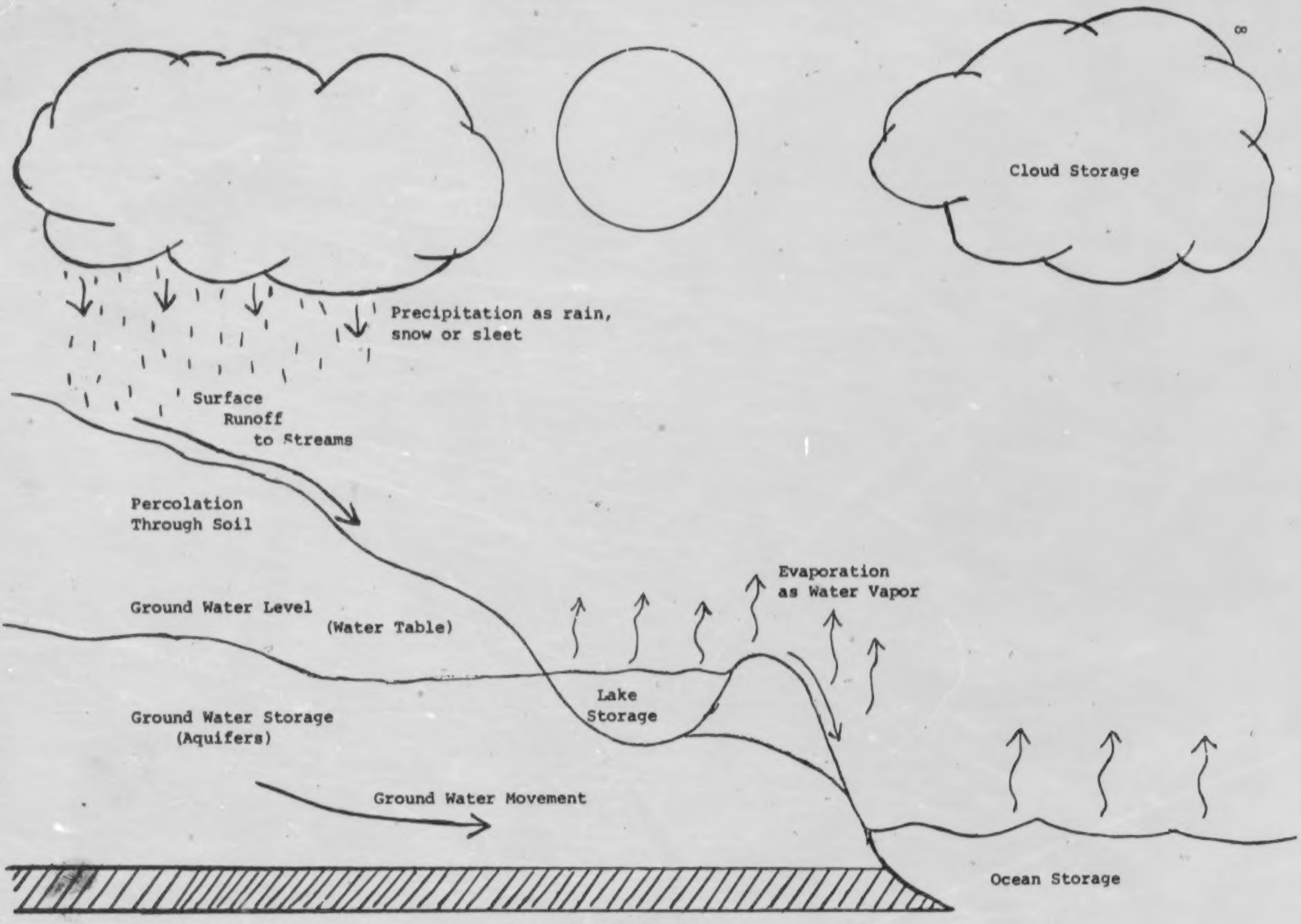
Another term for the movement of water is the hydrologic cycle. As we all know a cycle is a completed series of events which occur in a regular sequence. Thus a molecule of water will eventually return to original form. Let us follow a molecule of water through a cycle.

We can start anywhere in the cycle but for convenience let us start with a molecule of water in the ocean. This molecule of water is joined to other molecules of water in the form of a liquid. The heat of the sun will cause some of this liquid to evaporate or change from a liquid form to a vapor form. Since vapor is gaseous and lighter than air, it will rise. As it rises it enters cooler air and loses some of its heat. This causes the vapor to condense and form clouds. In these clouds water again turns into a liquid in the form of small droplets. Condensation is more rapid when a solid object or nucleus is present. These solid objects can be dust particles, smoke or airborne bacteria.

When atmospheric conditions are just right, the droplets of water come together. These then become too heavy to remain suspended in the air. At this time, water returns to earth in the form of rain, sleet or snow. Another word for this return to earth is called precipitation.

When water reaches the earth, some of it is immediately evaporated again. Some of it sinks into the earth while other parts of the water run in small streams toward lower elevations. That water which flows over the earth is called run-off. The water in this run-off will have impurities added to it when it comes into contact with human and perhaps animal wastes. These impurities can be in the form of bacteria, bits of dirt, sand and clay. The bacteria can cause disease while the particles of dirt can cause it to look muddy or turbid.

Run-off will eventually reach the ocean or a lake through streams and rivers. This then completes the hydrologic cycle. The molecule of water started at the ocean and ended there. A diagram of the hydrologic cycle is found on page 8 of this module.


Cloud Storage
Precipitation as rain,
snow or sleet
Surface
Runoff
to Streams
Percolation
Through Soil
Evaporation
as Water Vapor
Ground Water Level
(Water Table)
Lake
Storage
Ground Water Storage
(Aquifers)
Ground Water Movement
Ocean Storage

HYDROLOGICAL CYCLE

SELF-TEST

a.	Seventy-five precent of all fresh water is locked in_________________________________.	Polar ice caps and glaciers.
b.	A cycle is completed when a ________ ________ ________ occur in a regular sequence.	Series of events.
c.	The changing of water in liquid form to a vapor form is called ________.	Evaporation
d.	Water flowing over the earth is called ________?	Run-off

WATER SOURCES

Water sources can be divided into two major groups. These are surface sources and ground sources. Since we will talk about ground sources in another module, let us turn our attention to surface sources.

Surface sources consist of rivers, lakes, ponds and streams. From this source of supply 3/4 of the people of the United States draw their water. This is unusual since only 1/4 of the public water supply systems in this country are taken from this source.

In order to be an effective water treatment plant operator, one must keep in mind that surface supplies are not inexhaustable. Therefore one cannot use water at a rate which exceeds the rate of replenishment. In order to be able to draw water at a steady rate from a watershed, at or near the average rate of flow, the water must be stored during periods of high flow. The maximum rate at which the water can be withdrawn continuously over a long period of time is the safe yield of a watershed. This safe yield, without storage, would be equal to the future minimum flow rate which is expected. In other words, water can not be drawn from an area at a rate which exceeds the long term flow.

SURFACE WATER SUPPLIES QUALITY

From our examination of the hydrological cycle, we saw that pure water does not exist in nature. Because of waters chemical properties, it will pick up many contaminants. The amount and type of contaminant will depend on 1) what is dissolved in the water as it passes through the atmosphere, 2) the type of materials it picks up when it is in contact with the earth's surface and 3) the length of time it is in contact with the contaminants.

As explained in the Chemistry Module, the type of mineral contaminants present in water will depend on the geological formation it passes over. Another factor to consider is the watershed type. Runoff from arid and semiarid watersheds will often have high concentrations of dissolved minerals. These watersheds will also yield runoff with high turbidity. This is due to the sparse vegetation which will not prevent soil from washing into the water. On the other hand, runoff from humid areas will contain a lower concentration of dissolved minerals, a higher color and higher concentrations of organic materials such as leaves and branches. These contaminants result from the waters contact with plant life.

Water from streams and rivers is affected by the type of channel it passes through and the speed of the current. Suspended solids or turbidity will depend on the ease of channel erosion. Organic materials accumulate in slower streams and rivers at a greater rate than in waters which move faster. Water quality in streams and rivers is also affected by the presence of plankton (microscopic plants and animals). Large amounts of these organisms may cause taste, odor and turbidity problems. These types of surface water usually require more treatment than any other surface supply. This is due to the variance in the amount of turbidity, mineral content and pollution present from day to day.

Less treatment is usually needed for natural lakes and reservoirs. These sources may yield water of exceptionally fine quality except near the shoreline and in the neighborhood of sewer outlets. Turbidity is often low due to the ability of the water to permit suspended solids to settle out. Bacteria also tend to settle out in lakes and reservoirs. This settling phenomenon while helping to keep turbidity constant may cause problems for operators. This is because some of the suspended solids which settle out are iron and manganese. Under certain chemical and physical influence, these minerals will cause problems. (These influences will be described later in this section.) The removal of turbidity due to settling may also indirectly cause taste and odor problems. This is due to the increased light penetration. This along with adequate nutrients may stimulate algae growth which in turn may cause taste and odor problems.

Lakes and reservoirs will cause problems for the operator when influenced by certain chemical and physical phenomenon. For example, winds and rain may cause periodic increases in turbidity. Runoff from rain may increase the amount of soil carried into the body of water from the surrounding watershed and wind may cause the material on the shoreline and bottom to mix with the water. This increase in suspended solids may take some time to settle out. It is during this time that the operator must adjust his treatment processes to handle the change in contaminant levels.

Another phenomenon which influences turbidity and other mineral and gas contamination is called thermal stratification. This physical phenomenon results from the lake or reservoir's water dividing into layers of different temperatures. This stratification is a seasonal process. In the summer, the upper layers of the lake soaks up the heat provided by the sun. This heat slowly penetrates the water from top to bottom. If the body of water is deep, then the heat only penetrates the top few feet. For example a 30 ft. deep reservoir may be warmed to about 10-15 ft. That water which is deeper (15-30 ft) will stay from 5 to 20° cooler. As fall approaches the upper layer of water cools. This fact along with the action of fall winds will cause the warmer and cooler waters to mix. During winter the stratification of the water again appears in reverse. The colder water floats on top of a warmer layer of water. This stratification disappears in the spring when the top layer is warmed. Again mixing occurs with the help of spring winds. Mixing will also occur any time during the year when there are periods of high wind.

During periods of stratification, several problems may appear for the operator. This is due to the reduced amount of oxygen found in the lower layer of water. In this layer, oxygen will be used up by organisms present. Since this layer can not come in contact with the surface for more of the gas, the oxygen level steadily decreases. This low level will encourage the growth of bacteria which do not need oxygen to grow. In turn these bacteria can produce a gas, hydrogen sulfide, which has a disagreeable odor (rotton eggs). Low levels of oxygen will also help iron and manganese deposits on the bottom to dissolve. Later these minerals precipitate (become solid) in the distribution system to cause turbidity, color, taste and staining problems. In addition to these problems the pH of the lake or reservoir may decrease and the concentration of carbon dioxide may increase. These factors will affect the capabilities of the treatment facilities.

Problems may also be encountered by the operator during or after periods of mixing. Turbidity may increase due to the disturbance of bottom material. If the lake or reservoir contains a large amount of dissolved nutrients, mixing will distribute the nutrients throughout the system. This may stimulate aquatic growths causing taste and odor problems.

Many problems associated with stratification can be reduced before water treatment. This is done by the proper construction and location of intake structures which have openings at several elevations. If problems associated with stratification appear at one elevation, another which supplies the best raw water quality may be used.

Needless to say, problems with bacterial contamination are more prevelant in surface waters than ground waters. Discharges from waste treatment plants, sewage, and industry are often put directly into surface waters. These contaminants may vary from day to day so the operator must constantly monitor the water for them.

SELF-TEST

1. Water sources can be divided into two major groups. They are (1) __________ and (2) __________ sources.	surface ground
2. In this country, __________ of the people draw their water from rivers, lakes, ponds and streams.	3/4
3. The maximum rate at which the water can be withdrawn continuously over a long period of time is called the __________ __________ of a watershed.	safe yield
4. Water supplies from rivers usually require __________ treatment than any other surface supply.	more

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page refers to the topics discussed in this module which are found in that book.

1. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY, pp. 3-18.
2. Manual of Water Utility Operations, Texas Water Utilities Association, Austin, TX, pp. 40-54, 74-131.
3. Water Distribution Operator Training Handbook, American Water Works Association, pp. I-1 - I-5.

POST-TEST

1. Aquifers are:
   a. layers of rocks, sands or gravel containing water
   b. a type of tree
   c. a surface source of water
   d. none of the above
2. The movement of water over, under and on the earth is called:
   a. a stream
   b. hydrological cycle
   c. hydraulics
   d. precipitation cycle
3. The heat of the sun will cause water in lakes to change into a vapor. This process is called:
   a. precipitation
   b. evaporation
   c. condensation
4. Water vapor joining together in clouds is called:
   a. precipitation
   b. evaporation
   c. condensation
5. Turbid water is water which looks:
   a. clear
   b. blue
   c. muddy
6. Run-off may eventually reaches:
   a. the ocean
   b. streams
   c. lakes
   d. all of the above
   e. none of the above
7. The safe yield, without storage, is equal to the future
   a. minimum flow rate expected
   b. maximum flow rate expected
   c. optimum flow rate expected
8. Water supplies from rivers usually require more treatment than any other surface supply due to variation in
   a. turbidity
   b. mineral content
   c. degree of pollution
   d. all of the above
   e. none of the above

9. Natural lakes and reservoirs yield water of exceptional fine quality except:
   a. the middle of the lake
   b. near the spillway
   c. near the shoreline

10. Water droplets may form around particles of
   a. smoke
   b. ice
   c. airborne bacteria
   d. a and b
   e. a and c
   f. all of the above

ANSWERS

1. a
2. b
3. b
4. c
5. c
6. d
7. a
8. d
9. c
10. e

MODULE 10

SELF-INSTRUCTIONAL
Paul Hummel - NMSU

GROUND WATER

PREREQUISITES: Module Two - Basic Chemistry
Module Four - Microbiology
Module Seven - Chlorination
Module Eight - Plant Operations
Module Nine - Surface Water

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. True or False (1 pt. each)
   - a. With regard to a well, the radius of influence is not affected when the drawdown increases.
   - b. In passing through the ground, all iron is removed from well water.
   - c. Clear water is always safe water.
   - d. Water is made up of two atoms of H (hydrogen) and one atom of O (oxygen).
   - e. Lime is used to lower pH values.
   - f. Calcium is one of the constituents which causes hardness.
   - g. Fluorides are added to water for disinfection.
   - h. Magnesium sulphate in water causes mottled enamal on teeth.
   - i. pH is a mineral occuring only in ground water.
   - j. The pH value of 5.0 is acidic.
2. The primary use of lime in water treatment is to: (10 pts.)
   - a. reduce color
   - b. soften
   - c. remove tastes
   - d. disinfect
3. The neutral point on pH scale is: (10 pts.)
   - a. 0
   - b. 3
   - c. 7
   - d. 9
   - e. 14
4. One of the chemicals added to water to prevent it from being corrosive is: (10 pts.)
   - a. chlorine
   - b. lime
   - c. flourine
5. Hardness is not caused by: (10 pts.)
   - a. calcium
   - b. magnesium
   - c. sodium
   - d. iron
   - e. manganese
6. Flouridation can be accomplished utilizing: (10 pts.)
   - a. fluosilicic acid
   - b. sodium silicofluoride
   - c. sodium flouride
   - d. all of the above
   - e. none of the above
7. Characteristic of hard water is: (10 pts.)
   - a. soap consuming capacity
   - b. low pH
   - c. high specific gravity
   - d. pungent taste

8. According to acceptable standards, the iron content of a finished water should not exceed: (10 pts.)
   a. 1.0 mg/l
   b. 0.5 mg/l
   c. 0.3 mg/l
   d. 0.1 ppm

9. Most important factor to consider in location of a well site from the sanitation point of view is:
   a. distance from other wells
   b. anticipated yield
   c. availability of electric power
   d. soil conditions

10. Matching (1 pt. each)

1. Springs, aquifers, wells	a. surface water
2. Top of the zone of saturation	b. specific yield
3. Soil bound water	c. permeability
4. Total volume of open spaces between earth	d. radius of influence
5. Lakes, streams, ponds	e. ground water
6. Area from the well to the top edge of the cone of depression	f. drawdown of well
7. Water available for drainage	g. Greensand - Ziolite
8. Process to soften water	h. specific retention
9. Difference between static level and pumping level	i. porosity
10. Freedom water has to move in the soil	j. water table

ANSWERS

1. a. F
   - b. F
   - c. F
   - d. T
   - e. F
   - f. T
   - g. F
   - h. F
   - i. F
   - j. T
2. b
3. c
4. b
5. c
6. d
7. a
8. c
9. d
10. 1. e - ground water
    2. j - water table
    3. h - specific retention
    4. i - porosity
    5. a - surface water
    6. d - radius of influence
    7. b - specific yield
    8. g - Greensand - Ziolite
    9. f - drawdown of well
    10. c - permeability

INTRODUCTION

In one of the other modules (9 - Surface Water) you learned about the hydrological cycle and the unique problems you could encounter with surface water. In this module, you will continue your investigation of problems you could encounter with naturally occuring ground waters. The solutions to these problems as well as the subject of wells will be discussed here.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the following concepts:

1. Terms associated with ground water
2. Factors affecting presence and levels of ground water
3. Well types, construction and terms associated with wells
4. Contaminates of ground water
5. Methods of treating ground water

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if you answer it correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

HYDROLOGICAL CYCLE

In Module 9, the hydrological cycle was defined as the movement of water from one point to that same point after completing a series of events. In other words, a drop of water found in the sky will return to the sky after falling on the earth, traveling down a stream to a lake or ocean and then being evaporated back to the sky. We saw that this cycle can be complicated or simple. Water in clouds can fall as rain, sleet or snow and be locked up for years in a lake, ocean or glacier. Eventually this water may return to the sky as vapor through the process of evaporation. Water as it reaches the earth may also be absorbed by the ground. This module will discuss what happens to this ground water and how one may best use this source. It will also tell of the contaminations which are found in this source.

GROUND WATER

As stated in the module on surface water, 95% of the fresh water available in this country is ground water. Thus 80% of all U.S. public water systems use ground water. (Paradoxically more people are served by surface water than by ground water). Ground water supplies are drawn from springs, infiltration galleries and wells.

Water reaches these sources by penetrating the ground. As it does so, some of the water molecules are attracted to soil particles much like a magnet attracts iron filings. Other water molecules continue to travel downward attracted by the force of gravity to a layer in the earth called the zone of saturation. Here it collects and from which it feeds springs, flows into streams or supplies wells. That area above the zone of saturation (where the soil attracts the water molecules) is called the zone of aeration. The top of the zone of saturation is called the water table.

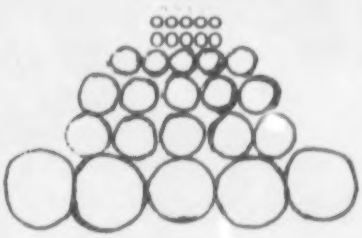
The water table and the zone of saturation may be different from place to place depending on the variation of elevation, consistency of earth materials, average annual precipitation and stream development. These factors will effect both the depth at which the zone is found as well as how much water is contained in it.

Three of the four factors effecting the zones need little explanation. Water will collect at the lowest part of its path. Therefore where the land slope is great such as a hill, the zone of saturation will be found deeper in the earth at the top of the hill than at the bottom. Rain or melted snow will raise the zone of saturation. If part of the zone of saturation encounters a body of water such as a stream and this zone is higher than the stream, water will tend to move into the stream. This movement will continue until the water table is level or below the surface of the stream. If no body of water is encountered then water may continuously collect in the zone of saturation depending on the other three factors. The consistency of the earth and how it effects ground water supplies may need a more detailed explanation.

POROSITY AND PERMEABLITY

Over the ages, the forces of nature has caused rocks to break down into smaller pieces. One of the most important of these forces is water. Water whether it be in the form of precipitation or moving ground water eventually wears down any hard object such as rocks that it encounters. It will also carry pieces of rock from one place to another. If it moves guickly such as water found in high elevation streams, it will transport great quantities of large rocks. As the stream slows down the heavier material falls to the bottom. This process continues until only the lightest material is found suspended in a slow or none-moving stream. Thus heavy large rocks fall to the bottom first, with the next heaviest rocks falling out next as the stream slows down. This process eventually results in a layer of top soil with the smallest diameter particles. The diameter of the soil gradually increases as one gets closer to the bottom. (Figure 1)

FIGURE 1

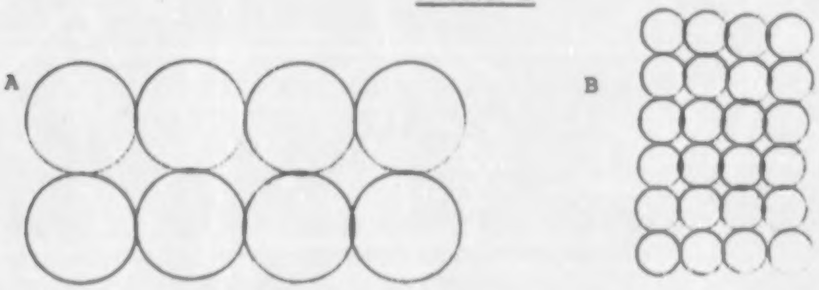


An important consequence of this natural sorting of earth materials into layers of various sizes is in the porosity of earth formed. One can define porosity as the total volume of open spaces between the earth. In other words the ratio of the total volume of the pore space to the total volume of the earth is its porosity. The more open spaces there are in a given area, the greater its porosity. Earth formations may contain any where from 1 to 50% porosity with the average formation being 5 to 20%. Anytime it is less than 5% the porosity is considered to be low. Greater than 20% is thought of as high porosity. As one goes lower in a formation one finds that the porosity generally decreases. This is due to the higher pressures from the material above. This pressure pushes together or compacts the soil grains leaving less air space.

While total porosity will give you some idea as to how much water a particular area will hold, it will not tell you how much water that area will yield. As we mentioned before, soil granules attract water like a magnet. Therefore some of the water in a certain area of the soil will be bound to the soil. When we talk about the term porosity we must remember that it is made up of two parts - that part bound to the soil and that which is free. Specific retention is the term applied to soil bound water. Specific yield deals with that water available for drainage.

Another factor which effects porosity is the permeability. Permeability refers to the freedom water has to move in the soil. If the soil is made up of large granules, water can move more freely than if the soil granules are small. Figure 2 shows how this is possible. The first diagram (A) has more space between the large soil particles than the second diagram (B). Therefore water can move faster through the larger granules.

FIGURE 2



In nature soil particles do not arrange themselves in the orderly fashion shown above. Instead large granules are mixed with smaller ones resulting in a variety of pore sizes and paths. One must therefore take into account, the size and number of pore as well as their degree of connections when determining the permeablity and porosity.

SELF-TEST

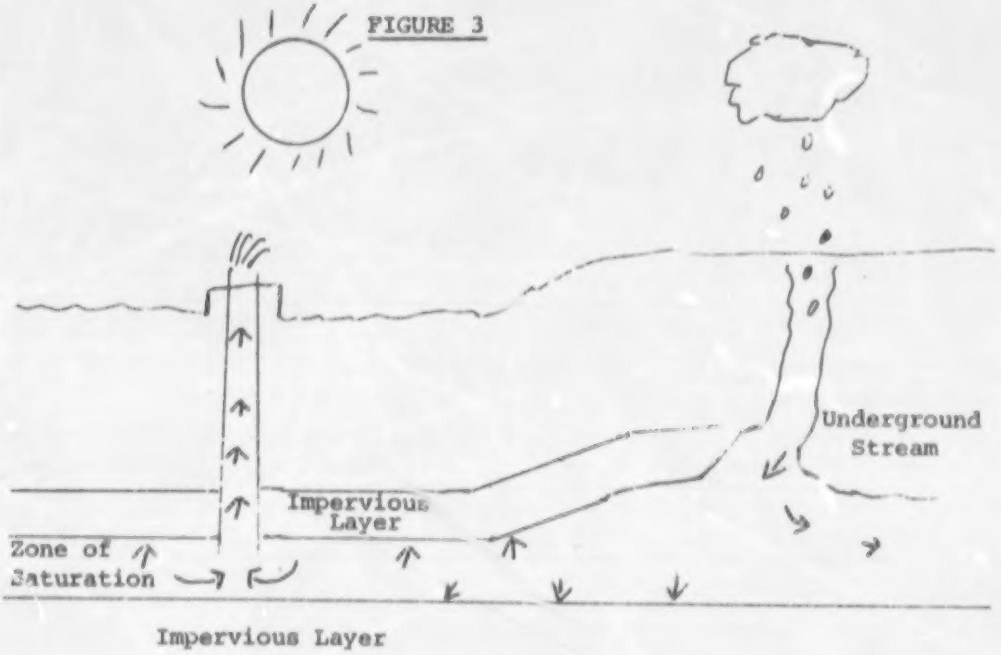
1. That area of the earth which contains and stores ground water is called the ________ ________ ________.	zone of saturation
2. The top of this area is called the ________ ________	water table
3. The ratio of the total volume of the pore space to the total volume of the earth is called its ________.	porosity
4. Porosity is made up of how many parts?	two
5. They are 1) ________ ________ and (2) ________ ________.	1) bound water 2) free water OR 1) specific retention 2) Specific yield
6. The freedom of water to move in the soil is called ________	permeability

AQUIFERS

In some places, there is enough water in the zone of saturation, that it can be tapped for use in wells. These places are called aquifers.

There are two types of aquifers, water table and artesian. Water table aquifers are ones in which the water is recharged through the soil above. Artesian aquifers are recharged from an underground source since the zone of saturation is covered by a layer of material with low permeability. Water from artesian aquifers is under pressure because its source is at a higher elevation and will rise in a well to an elevation above the top of the aquifer. See Figure 3.

FIGURE 3


Underground Stream
Impervious Layer
Zone of Saturation
Impervious Layer

Artesian Well

Source of water recharging well may be miles from the well.

WELLS

Water is drawn from aquifers through wells. The type of well used can be classified according to their depth or their method of construction. One can talk about deep wells or shallow ones. Deep wells being ones deeper than 100 ft. and shallow ones less than 100 ft. Today some people use a different criteria to classify wells according to depth. Shallow wells are considered to be ones which do not penetrate impervious strata. (Impervious strata are layers of material with very low permeability). Deep wells do penetrate impervious strata.

There are many types of wells. The State of Missouri under the Department of Natural Resources, Division of Environmental Quality has set design and construction standards for five types of wells. These are drilled, gravel wall, driven, dug, and bored wells.

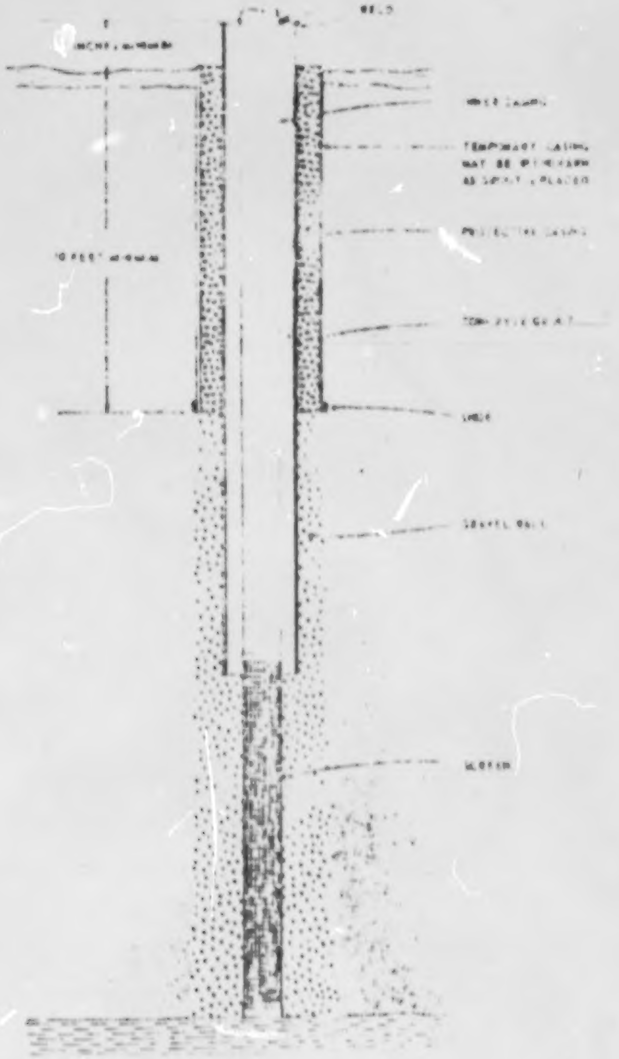
Wells which are drilled are the most commonly used today. These are formed by a rotary drill rig, hydraulic jet or cable tool rig. These wells usually will penetrate one or more water bearing formations. In construction, a water-tight casing seal will be placed in such a way to separate the various water bearing strata penetrated as well as to prevent surface water contamination. Drilled wells will provide excellent protection against contamination if properly constructed.

Gravel wall wells are drilled through caving formations. These types of wells will use gravel as a means of maintaining porosity in the area surrounding the well screen. Figure 4 shows a properly constructed gravel wall well. Water from these wells often contain iron, manganese, and occasionally bacteria, therefore treatment of shallow well water is often necessary.

Driven wells are created by a casing fitted with a suitable well point that is forced into an aquifer hydraulically or impacted by a driving head. This is an inexpensive method of tapping aquifers if the ground is free of rocks and the water table is not more than 50 or 60 feet deep.

Wells which are dug are usually shallow and created by hand. Wells formed by an auger are considered to be bored. These two types of wells as well as infiltration galleries and utilization of springs are allowed in Missouri only when geological conditions do not allow the construction of a satisfactory drilled well. These types of constructions must be protected from surface contamination by water-tight curbing and cover.

FIGURE 4


WELD
TEMPORARY CASING
MAY BE WITHDRAWN
AS GROUT IS PLACED
PROTECTIVE CASING
SHOE
GRAVEL WALL
SCREEN

Gravel Wall Well

(Taken from a Guide for the Design and Construction of Ground Water Supplies Storage and Distribution Facilities. Missouri Department of Natural Resources)

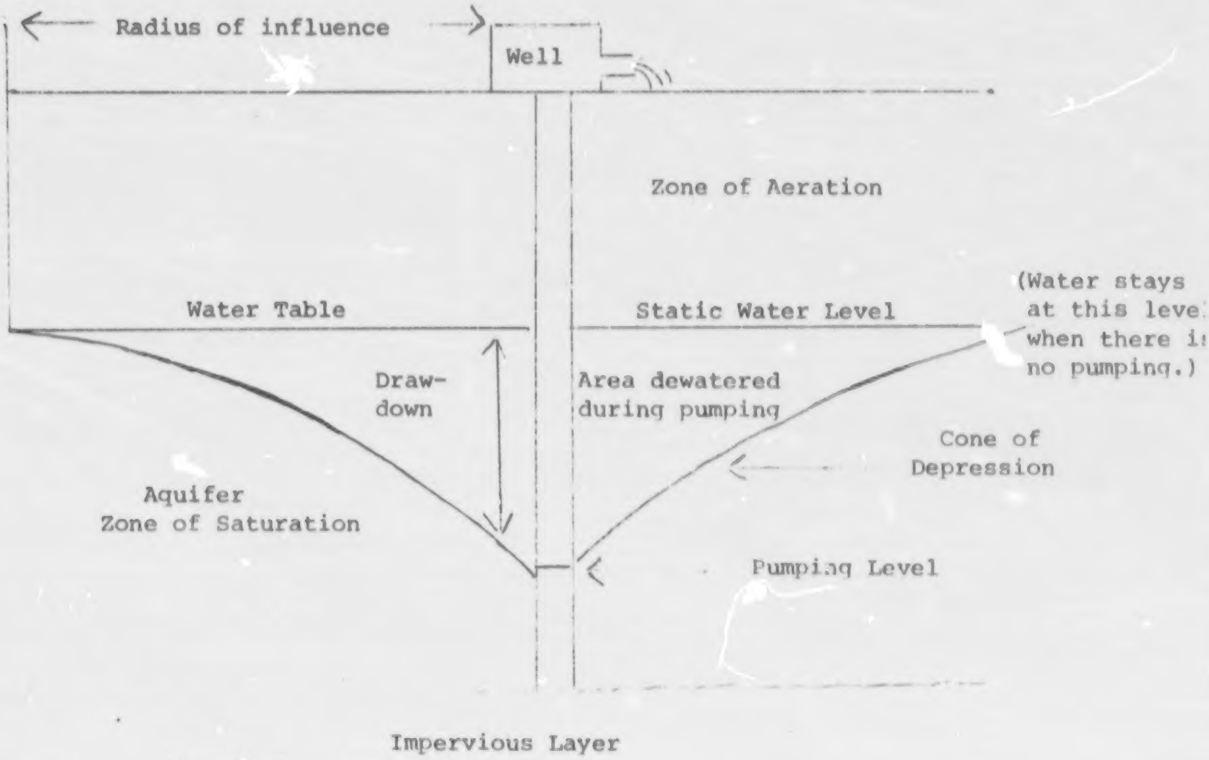
Information on the Missouri requirements for ground water supplies may be obtained from the Department of Natural Resources at the following address:

Missouri Department of Natural Resources
Division of Environmental Quality
P.O. Box 1368
Jefferson City, MO 65101

Wells tend to deplete some of the available water in an aquifer when they are operating. The dewatered area formed when aquifer water is being pumped is in the shape of a funnel. This area is called the Cone of Depression. The narrow end of this funnel is at the level the water has reached after it has been pumped awhile. This level is called the pumping level. When the well is not being pumped, the level of water present is called the static level. The static level will be above the water-bearing aquifer if the well is an artesian one. If the artesian well has water flowing out the top because of high pressure, the well is called a flowing well.

The difference between the static level and the pumping level is called the drawdown of a well. The area from the well to the edge of the top end of the cone of depression is called the radius of influence. One must be careful not to put two wells close enough together to allow the circles of influence to overlap. When this happens, mutual interference occurs and production of both wells will decrease. Figure 3 illustrates many of the terms described in the last few paragraphs.

FIGURE 5


Radius of influence
Well
Zone of Aeration
Water Table
Static Water Level
(Water stays at this level when there is no pumping.)
Draw-down
Area dewatered during pumping
Cone of Depression
Aquifer
Zone of Saturation
Pumping Level
Impervious Layer

SELF-TEST

1. The two types of aquifers are 1.__________ and 2. _________.	1. water table 2. artesian
2. Deep wells are deeper than __________ft.	100
3. The most common means today of forming most wells is by _________.	drilling
4. Area formed when aquifer water is being drained is called the _______ _______ _______.	cone of depression
5. The level of water present in wells not being pumped is called the ________ ________.	static level
6. Two wells close enough together to allow the circles of influence to overlap produces a condition called ________ _________.	mutual interference

WELL YIELDS

Several factors influence the yield of the well. They are as follows:

Depth of the aquifer
Composition of the aquifer
Diameter of the well
Temperature of the water
Amount of water flowing through the circle of influence

Deep wells usually yield a supply of water at a constant rate. This is because the water source is located at a distance from the well. Thus water is stored in the area between the source and the well so that fluctuations in rainfall and snowfall is averaged out. Shallow wells unlike deep wells depend on local precipitation to be recharged therefore their yield is not usually constant. The only exception to the rule that shallow wells do not yield a constant supply of water is in the case of gravel wall wells. These type of wells if found in river bottoms usually have very high capacities and seldom if ever are pumped down. The aquifer supplying this well is essentially an underground stream, recharged by a near-by river. While all gravel wall wells are not in river bottoms, yields from this type of well can be high if placed in extensive glacial deposits.

SANITATION

All wells should be protected from contamination. This can be accomplished by first locating the well at a safe distance from sources of pollution. These sources can include septic tanks, sewage treatment plants, farm animals and sewers.

Missouri has set forth standards concerning the minimum distances a well can be from a source of pollution. One hundred feet is the minimum permissable distance (300 feet recommended distance) from well site to sewage treatment plants, sewage pumping stations, outlets, disposal fields, septic tanks, privies and sewer lines of standard construction. Twenty-five feet is the minimum distance (100 feet recommended) allowed from well to sewer lines with cast iron construction (leaded, compressed or mechanical joints) and sources of pollution having aesthetic connotations such as animal pens and dumping grounds. These distances are recommended for approved drilled wells (approved by the Department of Natural Resources). Other types of wells may require greater distances.

A properly constructed well is another excellent means of preventing contamination. Pump houses should be clean, adequately drained and protected against flooding. To protect an aquifer against contamination, unused wells should be capped and abandoned wells sealed.

WELL MAINTENANCE

Over the years, the amount of water drawn from a well may decrease. This can be due to a number of factors such as heavy utilization of the aquifer, sand packing against the screen and encrusted screens. A good operator should exam the yield of a well frequently by measuring the static and pumping levels. If these measurements indicate a decreased yield over previous yields, the operator should identify the problem and correct it.

A decreased yield due to heavy usage can be corrected by lowering the pump. Another method would be to install a more powerful pump at the proper level.

Sand which may have packed against the screen can be loosened by exploding blasting caps. These should be placed in the screened portion of the well at two feet intervals. Surging with a surge block may also loosen the sand or any other encrusted matter.

An encrusted screen may be cleaned by means of inhibited muriatic acid (inhibited commercial hydrochloric acid). Brass, bronze or stainless steel screens can be cleaned in this manner but galvanized screens will be destroyed if acid cleaned. The amount of acid used will depend on the amount of encrustation present. The concentration can be determined roughly by comparing the specific capacity of the well and recovery time of the well with the figures initially measured when it was first placed in operation. Between 10 and 25 percent of the total volume of water in the casing (calculated from static level and pipe diameter) should be acid (10-25 percent solution). The length of time the acid remains in the well will vary according to the amount of encrustation on the screen (usually two to eight hours). After cleaning, the acid can be removed by reinstalling the pump and discharging the water to waste. Pumping should continue until the pH of the water is 7.0 or more and tests show that the acid has been completely neutralized. When this occurs the water can again be used.

Before using acid to clean well screens several precautions should be taken. First of all, the acid process should be done only under the supervision of a competent engineer or chemist. Several boxes of sodium bicarbonate should be placed conveniently near the operation to neutralize any spilled acid. All personel working on this type of project should be extremely careful to prevent acid spillage or splashing. If this does occur, rub dry soda on acid spots on clothing and frequently dip hands into the soda solution bucket while handling the acid.

Another factor which should be considered in maintaining a well is preventing bacteriological contamination. The top of the well should be kept sealed and sewers, privies and other potential dangers should not be placed near the well. Pumps or discharge columns withdrawn from wells should be carefully handled on the ground surface. This equipment should also be sterilized before putting it back into operation. Frequent bacteriological tests should be made on all wells.

SELF-TEST

1. __________ wells usually yield a supply of water at a constant rate.	Deep
2. What are the factors which influence the yield of a well.	Depth of the aquifer Composition of the aquifer Diameter of the well Temperature of the water Amount of water flowing through the circle of influence
3. The recommended distance between a well and sewer is usually suggested to be _______ ft.	300
4. The distance from a well and a cesspool should be __________ft.	300
5. Are these distances always constant? (Do they change?)	Yes

CONTAMINATION

As we saw in the module on Surface Water, water picks up various impurities even in the sky before it falls as precipitation. These impurities can be bacteria, dirt or particles of pollution. In addition, rain can pick up gasseous impurities. Some gasses such as carbon dioxide and sulfur dioxide are soluble in water. As precipitation falls to the earth these gasses and others are picked up by the water to form such substances as carbonic acid and sulfuric acid.

Water picks up additional contamination as it flows over, through and under the earth. This type of contamination comes from the dissolving of minerals in the water. Thus all natural water is contaminated to some extent.

Processed water which has all the dissolved substances removed does not have a pleasant taste. Therefore some substances are desirable. But water with too high a concentration of substances can not be used for some things. The amount of substances that can be present in a water supply and still be usable will vary with the type of contamination present and the type of use the water will get. Some common substances found in water and their effects are given in Table 1. The maximum limits required by the Safe Drinking Water Act for various substances are given in Table 2. Table 1 is taken from the AWWA manual of water supply practices number M21 on Ground Water (1973).

TABLE 1

Common Substance Found Dissolved in Ground Water

Substance	Effects
Gases	
Carbon dioxide	Corrosive to metals
Hydrogen sulfide	Corrosive to metals; odor; taste
Solids	
Sodium carbonate	Alkalinity (if in high concentrations)
Sodium bicarbonate	Alkalinity (if in high concentrations)
Sodium chloride	Taste; saltiness
Sodium fluoride	Mottles teeth (if in high concentrations)

TABLE 1 CONTINUED

Substance	Effects
Calcium carbonate	Hardness; alkalinity
Calcium bicarbonate	Hardness; alkalinity
Calcium sulfate	Hardness
Calcium chloride	Hardness; corrosive
Magnesium carbonate	Hardness; alkalinity
Magnesium bicarbonate	Hardness; alkalinity
Magnesium sulfate	Hardness
Magnesium chloride	Hardness; corrosive
Iron	Color; hardness; taste; staining
Manganese	Color; hardness; taste; staining

TABLE 2

Recommended limits for Some Chemicals Found in Drinking Water
(From Safe Drinking Water Act, 1974)

Substance	Concentration mg./l.
Arsenic	0.05
Barium	1
Cadmium	0.01
Chloride	250
Chromium (hexavalent)	0.05
Copper	1
Cyanide	0.01
Fluoride	0.7 to 1.2 is ideal (1.8 to 2.0 is maximum limit)
Iron	0.3
Lead	0.05
Manganese	0.05
Nitrate	10
Sulfate	250
Total dissolved solids	500

GROUND-WATER QUALITY DETERMINATIONS

Hydrogen-ion concentration (pH), acidity, alkalinity, total dissolved solids, chlorides, iron and hardness, are the most often conducted chemical determinations made to establish water quality. Bacterial samples are also taken to insure that the water is not contaminated with some type of pollution.

pH HYDROGEN-ION CONCENTRATION

In the Chemistry module, we described how a pure water molecule may be broken up into hydrogen (H+) and hydroxide (OH-) ions. If you remember, an ion was described as an electrically charged particle. The pH of water then describes the amount of hydrogen ions present in a solution. A pH of 7.0 is a neutral solution with equal amounts of H+ and OH- ions present. A pH of below 7.0 has more H+ ions than OH- ions and is considered to be acid. Above a pH of 7.0, there are more OH- ions than H+ ions. These solutions are considered to be basic. The average pH of ground water lies between 6 and 8.

Most acid conditions of water are the result of the presence of dissolved carbon dioxide. As water is utilized or aerated some of the carbon dioxide is released. Consequently, the pH of a well water can change. Thus, it is hard to obtain accurate pH values through measurements on average samples. Therefore, it may be a good idea to measure the carbon dioxide (CO_2) content of the well water.

ACIDITY AND ALKALINITY

When acids and bases are mixed, the usual result if water and a salt (usually dissolved). This is because the H+ and OH- ions are attracted to each other. They, therefore, will form water. The salt forms from whatever ions are left. This reaction does not normally occur in natural waters unless the pH is below 4.5. This is because of the presence of carbonate and bicarbonate ions. These ions present in waters below pH 7.0 and down to pH 4.5 will tend to neutralize free acids. This acid neutralizing quality is called alkalinity. Free OH- ions are very rare in ground water and is of little concern.

SODIUM AND POTASSIUM

Of the alkali metal ions, sodium and potassium are the most prevalent. Sodium is more common than potassium and is very soluble in water. Because of the solubility of sodium, problems of scale and precipitation are seldom encountered. An extremely alkaline water comes from the presence of either sodium carbonate or bicarbonate.

TOTAL DISSOLVED SOLIDS

The amount of dissolved mineral matter in drinkable water is often limited to 500 mg./l. by potable water standards. Water with more than this amount will often have an undesireable taste. These waters are corrosive and can be a major problem in the formation of scale in water heaters, boilers, etc.

CHLORIDE

In some waters, high chloride concentrations are a problem. These waters have a very salty taste. A high chloride concentration may mean that the aquifer is being polluted by wastewater.

IRON

Most ground water contains iron which can combine with oxygen when exposed to air. The resulting product of this combination is redwater. The recommended allowable concentration is 0.3 mg./l.. Higher concentrations may cause problems such as staining, tastes, and odors. Frequently a type of bacteria found in water will use this iron to form a sheath around their colonies. When this happens, clogging problems can occur in wells and pipes.

HARDNESS

The hardness of almost all water supplies is due mainly to the presence of calcium and magnesium. To a lesser degree iron and manganese also contribute to water hardness.

Hardness of water resulting from calcium and magnesium is due to the following process. We know that carbon dioxide (CO_2) readily dissolves in water. When the water containing carbon dioxide (CO_2) comes in contact with either calcium ($CaCO_3$) or magnesium ($MgCO_3$) salts found in many rocks, the reaction results in the formation of bicarbonates of calcium ($Ca(HCO_3)_2$) and magnesium ($Mg(HCO_3)_2$).

$$CaCO_3 + CO_3 + H_2O) = Ca(HCO_3)_2$$

Calcium + Carbon dioxide + Water = Calcium bicarbonate

$$MgCO_3 + CO_2 + H_2O = Mg(HCO_3)_2$$

Magnesium + Carbon dioxide + Water = Magnesium bicarbonate

The hardness of water varies from area to area reflecting to some degree the geological formations with which the water comes in contact. Hardness is normally expressed in terms of calcium carbonate ($CaCO_3$) as parts per million.

In general, there are two kinds of hardness: carbonate and noncarbonate.

Hardness due to the presence of bicarbonates of calcium ($Ca(HCO_3)_2$) and magnesium ($Mg(HCO_3)_2$) is called carbonate hardness. If nothing happens to upset the balance of the carbonates and bicarbonates and their associated ions (calcium and magnesium), this type of hardness is not harmful. Unfortunately any small chemical or physical change, i.e. heat, pH, will cause the calcium and magnesium to precipitate (form a solid material). This precipitate can in turn clog pipes and leave deposits on the bottom of tanks.

On the other hand, hardness due to the presence of the ions of sulfates, chlorides, or nitrates of these elements (Ca, Mg) is called noncarbonate hardness. While calcium and magnesium will not readily presipitate out of solutions containing the above ions, noncarbonated hardness is important for the damage it may cause. For example, the sulfates may eventually form scale and the chlorides can be corrosive to some materials.

BACTERIA

Ground water is also examined for bacterial contamination. While this source of water usually contain fewer bacteria, there is always the possibility of contamination from improper well construction or pollution of the water charging the underground water source. See the Microbiology module for further details.

SELF-TEST

1. The measurement of H+ and OH- ions is called __________.	pH
2. Acid water results from the presence of __________ __________.	carbon dioxide
3. Acid neutralizing properties of water is often called __________.	alkalinity
4. Alkalinity is caused by the presence of ______ ions ______ ions and ______ ions.	carbonate bicarbonate hydroxide
5. Water with a mineral content of over 500 ppm are often __________.	corrosive
6. A type of bacteria uses this element to form a sheath around its colonies, this element is __________.	iron
7. What happens when this bacteria and element is found in plumbing?	clogging of plumbing can occur
8. The two types of hardness are __________ and __________.	carbonate noncarbonate

GROUND WATER TREATMENT

Ground water is usually free of turbidity, color and organic materials. This is because of the filtering process it undergoes as it passes through the earth. Little treatment of the water is needed unless it has a high content of dissolved gasses and minerals. Some of the means of conditioning or treating ground water for specific contaminants are given below.

AERATION

To oxidize iron and manganese, remove hydrogen sulfide, carbon dioxide and methane, one commonly aerates the water. In the case of dissolved gasses, air bubbles passed through the water will release these contaminates to the air. Aeration will cause the iron and manganese contaminates to combine with oxygen. This process causes a precipitate to form. Filtration of these precipitates is then the next step in processing waters which contain iron and manganese.

SOFTENING

As stated earlier, there are two types of hardness, carbonate and non-carbonate. If either of these types of hardness is present in water in large amounts, undesirable reactions may occur. For example hardness destroys the power of soaps and detergents, leaves scale on pipes, boilers and cooking utensils, causes some skin diseases and shortens the life of laundered fabrics. The removal of water hardness is called softening.

Greensand-Zeolite Process (Sodium Zeolite or Ion Exchange)

In this softening process silicate compounds are used as a base for exchange between sodium and calcium or magnesium. While there are natural rock formations which have the ability to serve as a base for the exchange, synthetic resins are often used because of their greater effectiveness. Upon exhaustion of the exchange capability of the resin it is regenerated with a brine solution.

Lime-Soda Process

This process is often used in larger plants with skilled operators. It is very desirable process to be used with waters with high mineral content because it not only will cause the hardness-causing minerals to precipitate but will also cause iron and manganese to precipitate as well. This process requires a high pH. The equipment required to use this process often includes bulk lime feeders, chemical mixing chambers, flocculation and settling basins, recarbonation units, filtering beds, and sludge handling equipment. More details of the Greensand-Zeolite Process and Lime-Soda Process can be found in the module on Plant Operations.

FLUORIDATION

Fluoride is present in natural waters in varying amounts. In drinking water, fluoride has been shown to prevent tooth decay. However, too much fluoride will cause teeth to stain while too little fluoride will not have a beneficial effect. The recommended level of fluoride in water is approximately 1.0 mg./l. and it should not exceed 2.0 mg./l. Sodium fluoride, powdered sodium silicofluoride or hydrofluosilicic acid are used as a means of adding fluoride to drinking water.

CHLORINATION

Ground water is often chlorinated to insure disinfection and in certain situations is used to destroy odors (including hydrogen sulfate) and in aiding the oxidation of iron. Missouri requires the disinfection of all water supplies that are not of safe sanitary quality. Only chlorine or chlorine compounds such as liquid chlorine, calcium or sodium hypochlorites, or chlorine dioxide are approved for disinfection by the state. A free residual of at least 0.5 ppm is required by Missouri after a minimum contact time of one hour in a detention basin. (See Module 7 for details of Chlorination.)

SELF-TEST

1. What method is used to treat and/or remove these contaminates:	
Iron and mangenese	aeration and filtration
Calcium and magnesium	Softening: Greensand-Zeolite Lime-Soda
Bacteria	chlorination
2. Lime will _________ the pH of the water.	raise
3. The recommended level of fluoride is _______________ ppm.	1.0
4. Fluoride prevents ______ ________ in children.	teeth decay

GROUND WATER: ADVANTAGES AND DISADVANTAGES

We have, in this module, discussed some of the basics involved in the use of ground water. You should also be aware of some of its advantages and disadvantages as compared to surface water sources.

Ground water is usually clearer and contains less bacteria than surface sources. It is easier to treat if it is taken from a single well. This is because single wells will usually have a uniform mineral content. The temperature of the water from this source is usually more constant and lower in the summer and icing problems are usually fewer in the winter than surface water. This source is suitable for smaller communities, private homes and isolated industrial plants.

Some disadvantages on the other hand are that it is an uncertain and scarce supply source for large consumers. In some localities, the calcium and magnesium compounds are present in larger quantities than surface waters found in the same area. Iron, manganese and hydrogen sulfide are often present. Its pumping cost is usually greater than pump surface water. One other disadvantage in utilizing ground water sources lies in the treatment of water from two wells. The mineral content from two wells may be entirely different even though located on the same plot of ground. Thus the treatment process could be complicated because the water for each source will require different quantities of softening chemicals.

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY pp. 10-11.
2. Manual of Water Utility Operations, Texas Water Utilities Association, Austin, TX pp. 19-39.
3. Operation of Wastewater Treatment Plants, California Water Pollution Control Association, Environmental Protection Agency, Sacramento, CA Chapters I, II.
4. Ground Water, AWWA. Manual M21, AWWA, New York, NY pp. 130.
5. Safe Drinking Water Act. Information about this act can be obtained by writing to:

   United States Environmental Protection Agency
   1735 Baltimore
   Kansas City, MO 64108

   or

   AWWA
   6666 W. Quincy Ave.
   Denver, CO 80235

6. For information on the design and construction of ground water supplies storage and distribution facilities, please write:

   Missouri Department of Natural Resources
   Division of Environmental Quality
   P.O. Box 1368
   Jefferson City, MO 65101

POST-EVALUATION (10 pts. each question)

1. True or False (2 pts. each)
   a. Hydrogen sulfide gas in a water supply can only be removed by sand filtration.
   b. Water is aerated to allow iron to escape into the air.
   c. Iron in water is injurious to health.
   d. All waters are equal in their corrosive properties.
   e. Water having fluoride contents of 1.4 part per million will significantly reduce tooth decay in children.

2. Under no circumstances should a well be located closer than a horizontal distance of __________ feet from a privy, cesspool or tile sewer.
   a. 10
   b. 25
   c. 50
   d. 100

3. What gas is common to all groundwater supplies?
   a. hydrogen sulfide
   b. oxygen
   c. carbon dioxide
   d. carbon monoxide

4. The difference or distance between the static level and the pumping water level is:
   a. water table
   b. zone of saturation
   c. zone of retention
   d. drawdown
   e. circle of influence

5. Generally, groundwater has a higher mineral content than surface water because:
   a. it has no dissolved carbon dioxide
   b. it has no silica content
   c. it contains less sulfates than surface water
   d. none of the above

6. A well supply is high in iron. To remove it, the following should be required:
   a. retain until it settles out
   b. pump it as it is
   c. aerate and settle
   d. carbonate it with CO_2

7. The major constituents of hardness are:
   a. calcium
   b. magnesium
   c. iron
   d. manganese
   e. all of the above
   f. none of the above

8. The water table level and zone of saturation may vary due to:
   a. variation of elevation
   b. consistency of earth materials
   c. average annual rainfall
   d. stream development
   e. all of the above
   f. none of the above

9. Porosity is considered to be low if it is:
   a. less than 5%
   b. 5% to 20%
   c. 20% to 35%
   d. over 35%

10. Water from a well is clear when pumped but turns cloudy upon standing a short while. It also stains pipes an orange-red. What impurity is indicated?

ANSWERS

1. a. F
   b. F
   c. F
   d. F
   e. T

2. d

3. c

4. d

5. d

6. c

7. e

8. e

9. a

10. Fe (Iron)

MODULE 11

SELF-INSTRUCTIONAL

James H. Shaddy - NMSU

PUMPS

PREREQUISITES: Module One - Basic Mathematics
Module Six - Hydraulics

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. True or False (20 pts. total; 4 pts. per question)
   - a. A centrifugal pump is a device that pressurizes a liquid by centrifugal force created by a wheel called an impeller, revolving in a tight casing.
   - b. The most commonly used pump today is the displacement pump.
   - c. When selecting a pump you should consider the chemical properties of the water.
   - d. The vertical distance from the water supply level to the pump centerline with the pump above the supply level is known as static suction lift.
   - e. The squirrel cage is the simplest type of electric motor.
2. What is an impeller? (4 pts.)
3. In the __________ type centrifugal pump, the impeller discharges the water into the surrounding spiral casing. (4 pts.)
4. If you have a pump that is operating with a water horsepower of 50 and a brake horsepower of 100. What is the efficiency of the pump?
5. If the packing gland is leaking excessively you should (4 pts.)
   - a. tighten it further
   - b. replace a few of the packing rings
   - c. replace the lantern ring
   - d. replace all of the packing rings in the packing gland
6. Match the correct description with the appropriate centrifugal pump part (36 pts. total; 4 pts. per question).
   1. Shaft sleeve _____
   2. Sealing water _____
   3. Bearings _____
   4. Wear rings _____
   5. Impeller _____
   6. Shaft _____
   7. Coupling _____
   8. Case _____
   9. Packing glands _____

   - a. supports, aligns and rotates impeller
   - b. connects pump to motor
   - c. keeps air out and water in case
   - d. support and allows shaft to turn
   - e. converts rotary motion of the motor and shaft to water velocity
   - f. converts water velocity to water pressure
   - g. replaceable item that takes the wear of the packing gland and protects the shaft
   - h. cools, reduces wear, and increases the efficiency of packing glands
   - i. prevents circulation of water between impeller suction and discharge.

7. Name 7 of the 8 items that should be checked routinely on a pump to ensure proper operation and maintenance. (4 pts. each).
   a.
   b.
   c.
   d.
   e.
   f.
   g.

ANSWERS

1. a. T
   b. F
   c. T
   d. T
   e. T

2. A propeller like device that picks up the water as it moves along the pump shaft and converts the rotary motion of the motor and shaft to velocity of water.

3. Volute

4. 50%

5. d

6. 1. Shaft sleeve - g
   2. Sealing water - h
   3. Bearings - d
   4. Wear rings - i
   5. Impeller - e
   6. Shaft - a
   7. Coupling - b
   8. Case - f
   9. Packing glands - c

7. a. pump pressure and output
   b. bearings
   c. motors
   d. control equipment
   e. pump operation
   f. packing glands
   g. shaft sleeves and wearing rings
   h. alignment

INTRODUCTION

Water that is provided for public use is delivered under pressure. In a few systems this can be accomplished by gravity. But generally, pumps are used. This module will present basic information on the operation and maintenance of pumping units and drivers. Some of the material used in this module is reprinted with permission of the American Water Works Association from the "Water Distribution Operator Training Handbook", Copyright 1976.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the following concepts:

1. Types of pumps
2. Terms associated with pumps and pumping
3. Major sources of Power or Prime movers for pumps
4. Determine pump efficiency
5. Types, construction, operation and maintenance of Centrifugal pumps

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the questions. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

TYPES OF PUMPS

The majority of pumps used in water-utility systems can be identified as either positive displacement or centrifugal units.

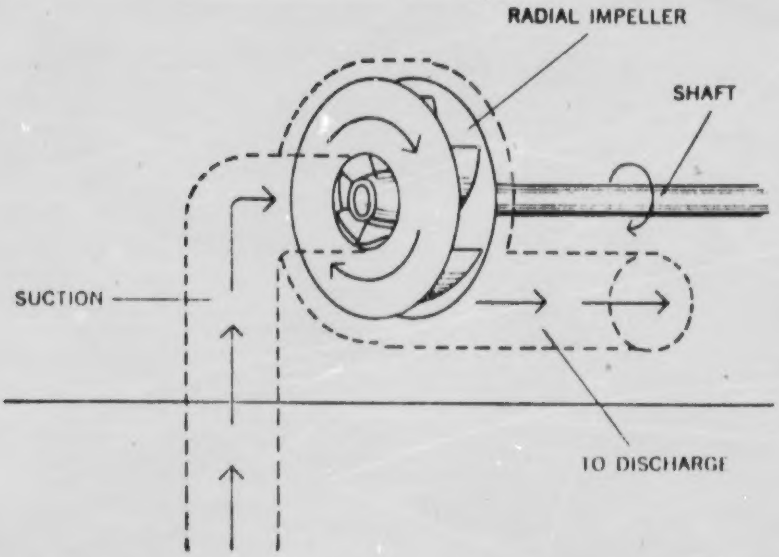
The most commonly used pump today is the centrifugal pump. It consists of an impeller or impellers rotating in a casing. The water is essentially picked up by the impeller vanes at its center and through centrifugal force develops the energy needed to force it radially out of the casing discharge outlet (Figure 1). This causes a vacuum condition at the eye or center thus providing the necessary condition to move the water.

The double suction centrifugal pump has the impeller constructed in such a way that there are two water entrances and only one discharge.

Two other related types of centrifugal pumps are the mixed-flow pump (Figure 2) where the head is formed partly by centrifugal force and partly by the lift of the vanes on the water, and the axial flow or propellar pump (Figure 3) where most of the head is developed by the lifting action of the vanes on the water.

FIGURE 1

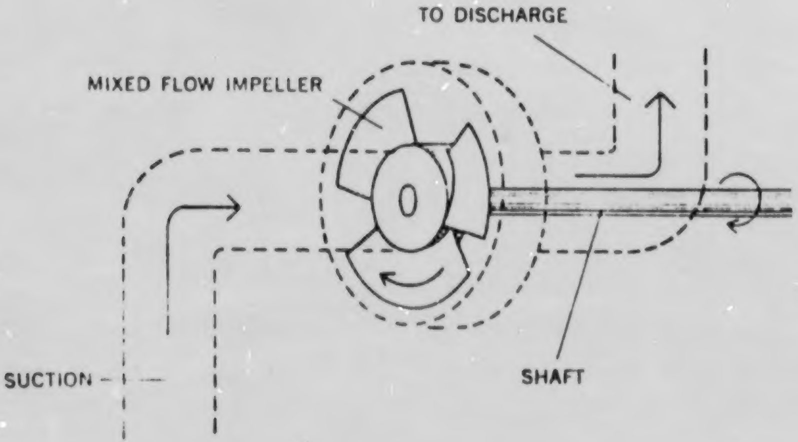
Radial-Flow Pump



(Source: "Water Distribution Operator Training Handbook." 1976, AWWA.)

FIGURE 2

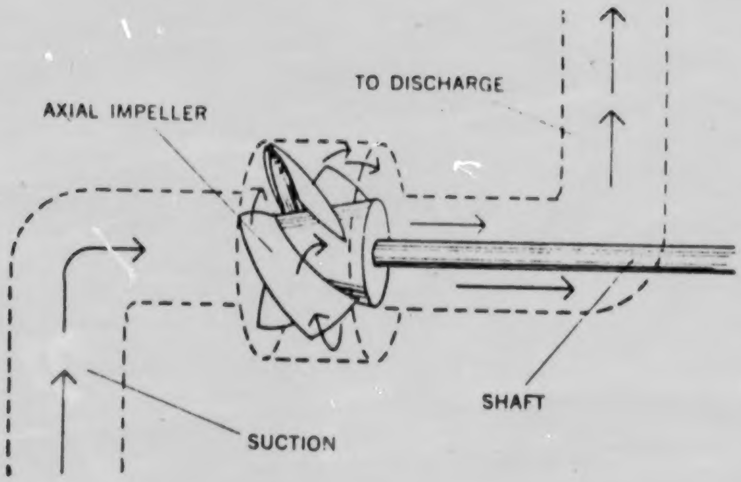
Mixed Flow Pump


TO DISCHARGE
MIXED FLOW IMPELLER
SUCTION
SHAFT

(Source: "Water Distribution Operator Training Handbook." 1976, AWWA.)

FIGURE 3

Axial-Flow or Propeller Pump


TO DISCHARGE
AXIAL IMPELLER
SHAFT
SUCTION

(Source: "Water Distribution Operator Training Handbook." 1976, AWWA.)

Displacement pumps can be divided into piston and rotary types. The piston pump (Figure 4) operates by the use of a piston, plunger, diaphragm or similar device. Movement of this device (Piston) in one direction draws water in through a valve. Then movement in the opposite direction forces the water out through a second valve. This causes the water to be positively displaced during each stroke of the unit. The power that operates the pump is applied to a crank and flywheel or directly to the crankshaft. This is in turn connected to the piston, plunger or diaphragm which is enclosed in a cylinder or case. As these parts are moved, they either displace or discharge the water or draw water into a case or cylinder. Generally, these types of pumps are used as auxiliary pumps where heavier liquids or solutions are being pumped. The rotary pump (Figure 5) also operates by using position displacement. It consists of a casing containing gears, cams, pistons, etc. to trap a volume of water drawn into the pump intake and carry it around or push it around until it is discharged.

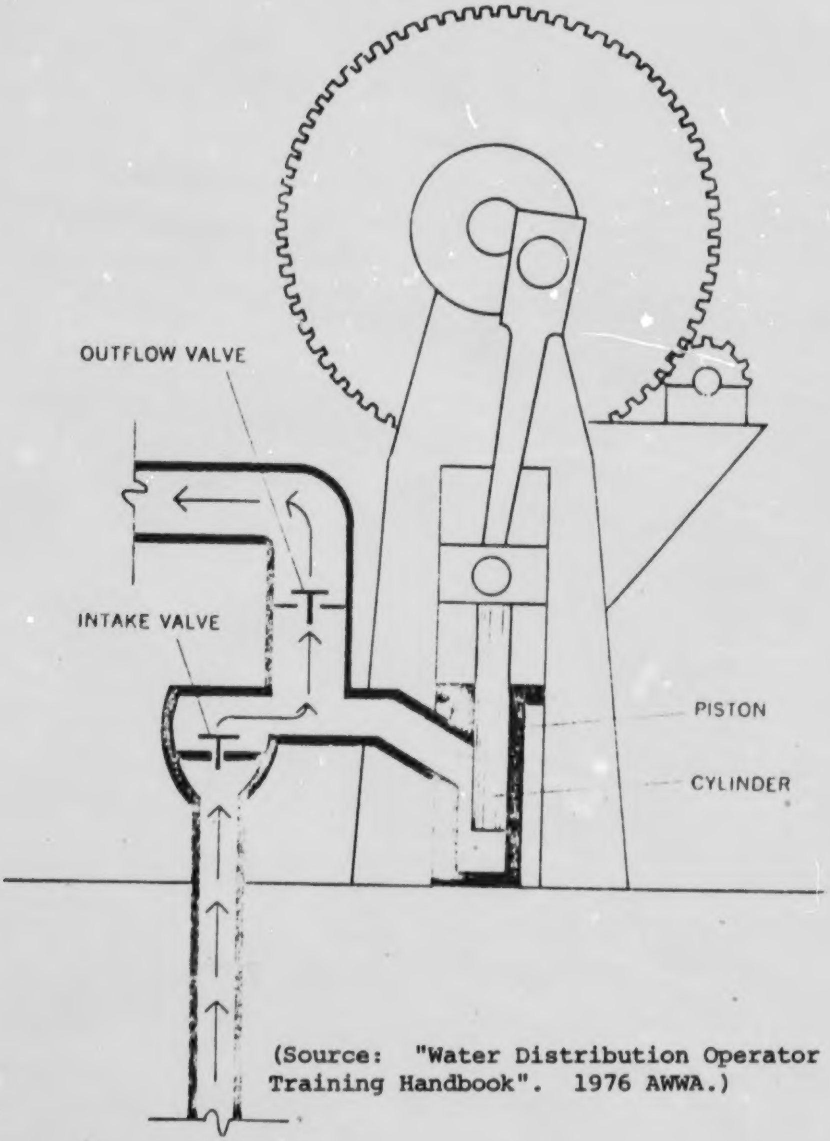
Below are listed several factors that one should consider when trying to determine the type of pump to purchase.

1. Costs
2. Capacity needed
3. Source of water (surface or well)
4. Properties of water (chemical and physical)
5. Total head
6. Type of available power

It is usually desirable to install duplicate pumps when possible. This allows one to be removed from operation for maintenance, overhaul, painting, etc. without affecting ability of the plant to pump water.

FIGURE 4

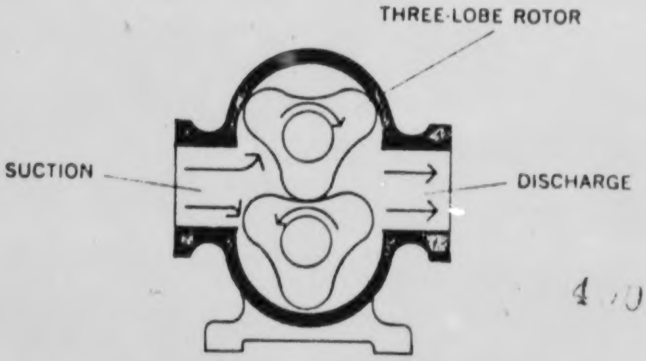
Piston Pump


OUTFLOW VALVE
INTAKE VALVE
PISTON
CYLINDER

(Source: "Water Distribution Operator Training Handbook". 1976 AWWA.)

FIGURE 5

Rotary Pump


THREE-LOBE ROTOR
SUCTION
DISCHARGE

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

DEFINITION OF TERMS (Figure 6)

Head - the distance (height) to which a body of water would rise if it were not contained. Thus head is a measure of water pressure (feet of liquid; pounds per square inch; or inches of mercury).

Static Suction Lift - the vertical distance from the water supply level to the pump centerline with the pump above the supply level.

Static Suction Head - the vertical distance from the water supply level to the pump centerline with the pump below the supply level.

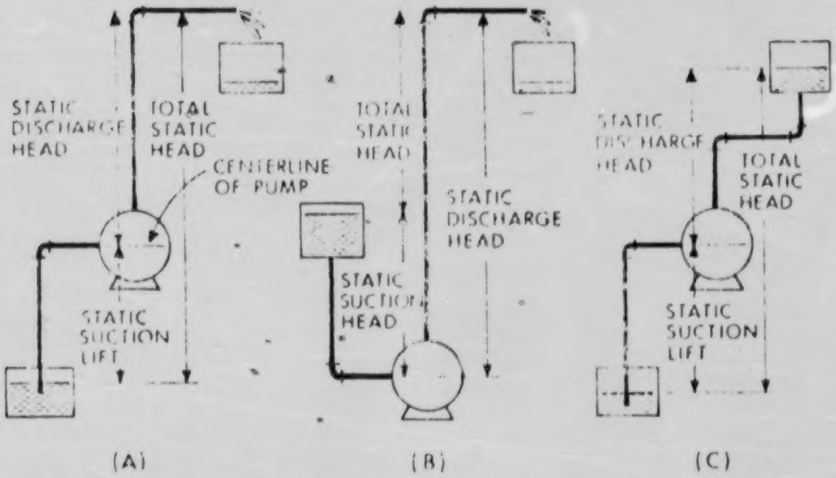
Static Discharge Head - the vertical distance from the pump centerline to the point of free delivery of the water.

Total Static Head - the vertical distance between the supply level and the discharge level of the water being moved.

Friction Head - the equivalent head needed to overcome the resistance of the pipe, values, and fittings in the pumping system. This occurs on both the suction and discharge sides of the pump.

FIGURE 6

Head Terms Used in Pumping


STATIC DISCHARGE HEAD
TOTAL STATIC HEAD
CENTERLINE OF PUMP
STATIC SUCTION LIFT
(A)
TOTAL STATIC HEAD
STATIC DISCHARGE HEAD
STATIC SUCTION HEAD
(B)
STATIC DISCHARGE HEAD
TOTAL STATIC HEAD
STATIC SUCTION LIFT
(C)

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

Entrance and Exit Losses - head losses that occur at the entrance and exit of the piping and at abrupt changes in piping sizes.

Friction Losses - loss of energy brought about by the friction of the water moving through the pipe. These losses have been tabulated for all standard pipe sizes and pipe conditions for various velocities.

Suction Lift - the sum of the static lift, the suction friction head and entrance loss in the suction pipe. The source of the liquid is below the center line of the pump. This generally results in a negative pressure condition at the suction nozzle. Theoretically it should be possible to lift water at sea level a maximum of 34 ft. under ideal conditions. However these conditions seldom occur in actual practice. All pumps have suction lift limitations determined by their size, design, and operating conditions. The modern centrifugal pumps can achieve a suction lift capability up to 20 ft. without affecting other performance characteristics. Displacement pumps can achieve a suction lift up to 25 ft. Pumps designed for a certain capacity and discharge pressure will have a suction lift rating determined by the manufacturer.

Suction Head - the static suction head minus the suction friction head and suction piping entrance loss. The source of the liquid is above the center line of the pump. This generally results in a positive pressure at the suction nozzle.

Capacity - every pump will be given a capacity rating by its manufacturer in either gallons per minute or million gallons per day. This rating is dependent on the suction or discharge condition, or the speed of the motor.

Operating (total) Head - combines both the conditions of suction and discharge into a single term.

Example 1 (Figure 6)
60 ft. = static discharge head
10 ft. = static suction lift
1 ft. = suction line loss (friction)
3 ft. = discharge loss (friction)
60 + 10 + 1 + 3 = 74 ft. (operating head)

Example 2 (Figure 6)
60 ft. = static discharge head
10 ft. = static suction head
1 ft. = suction line loss (friction)
3 ft. = discharge loss (friction)
60 - 10 + 1 + 3 = 54 ft. (operating head)

Water Horsepower - the head and capacity output in terms of horsepower power.

$$\text{Water Horsepower} = \frac{\text{Operating head x pump capacity (gpm)}}{3960}$$

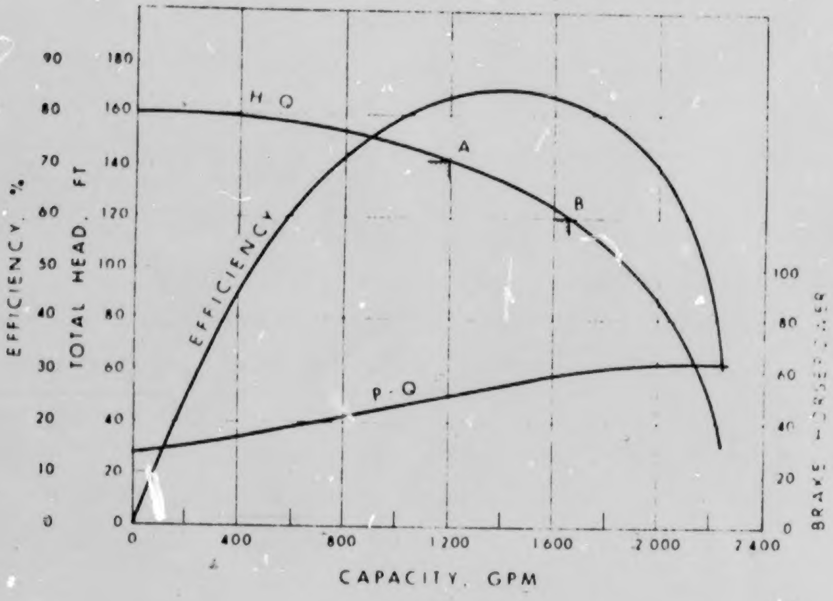
Brake Horsepower - the power that is applied by the driver to the pump shaft. The manufacturer will supply this information since any change in rated suction, discharge, or flow conditions will in turn change the rated brake horsepower.

Pump Efficiency - the pumps ability to convert brake horsepower to water horsepower expressed in percent. The water horsepower will always be smaller than the brake horsepower because of energy (friction) losses within the pump i.e. wearing ring clearance, impeller slippage. As operating conditions change, the pump efficiency changes (Figure 7). This information is generally supplied by the manufacturer.

$$\text{Pump Efficiency} = \frac{\text{Water Horsepower x 100}}{\text{Brake horsepower}}$$

FIGURE 7

Pump Performance Curves



(Source: "Water Distribution Operator Training Handbook. 1976, AWWA.)

The above performance curve (Figure 7) illustrates how the efficiency and capacity of a pump can be affected by changing either the discharge or suction conditions (total head) or the speed of the motor (brake horsepower). In this example the pump operates most efficiently with a total head between 120 and 140 ft. and brake horsepower between 50 and 60. This results in an 82% or better efficiency while pumping between 1200 and 1600 GPM.

Thus when choosing a pump for a particular system, it is important to know the capacity and total head needed in order for you to select a pump that will operate efficiently.

SOURCES OF POWER FOR PUMPS

The major types of prime movers (power) used in pumping operations are steam-driven engines; hydraulic turbines; electric motors; and oil, gas or gasoline-driven internal combustion engines.

The electric motor has gradually become the most popular source of power to drive pumps primarily because of cheap electricity, reliability, ease of automation, and quieter operation.

The main types of electric motors in use are the squirrel cage, the wound-rotor and the synchronous.

The squirrel cage type is the simplest, most reliable and least expensive. It is used where constant speed is required.

The wound-rotor can be brought up to speed gradually and the speed changed as needed. Consequently, it is used to change pump capacity by changing speed.

The other types of prime movers are generally not used as the main power unit because of high cost of maintenance upkeep, need for continuous fuel supply and upkeep and high initial cost. However, they are used for augment services and for standby service.

SELF-TEST

1. Describe how a centrifugal pump works.	The water is picked up by the impeller vanes at the center and through centrifugal force developed by rotation of the impeller, acquires the energy needed to force it radially out of the casing discharge outlet.
2. Describe how a displacement pump works.	Movement of the piston piston, plunger, diaphragm or similar device in one direction draws in the water through a valve. Then movement in the opposite direction forces the water out through a second valve.
3. List the six factors that should receive consideration when purchasing a pump.	a. cost b. capacity c. source of water d. properties of water e. total head f. type of power available
4. Determine the operating head for the following situation: 50 ft. = static discharge head 5 ft. = static suction lift 1 ft. = suction line loss (friction) 3 ft. = discharge loss (friction)	59 ft.
5. Determine the efficiency of a pump operating under the following conditions: operating head = 50 ft. pump capacity = 600 gpm brake horsepower = 30	25.25%
6. Which of the following prime movers is the most popular power source today? a. steam-driven engines b. electric motors c. hydraulic turbines d. gas, oil or gasoline-driven engines	b

CENTRIFUGAL PUMPS

Centrifugal pumps operate basically the same. However, there are several different designs, arrangements and types.

The four main types of centrifugal pumps are volute, turbine, multistage, and deep-well turbines.

The volute pump is probably the most common centrifugal pump in use today. This pump is designed such that the impeller discharges the water into the surrounding expanding spiral casing. Thus the high velocity or energy of the pump is reduced and converted to the form of energy we call static pressure force or head.

Multiple stage pumps employ the use of two or more impellers on the same shaft (Figure 8). This pump is used where a high operating head is required since the pressure and velocity of the water are increased as it moves from one stage to the next.

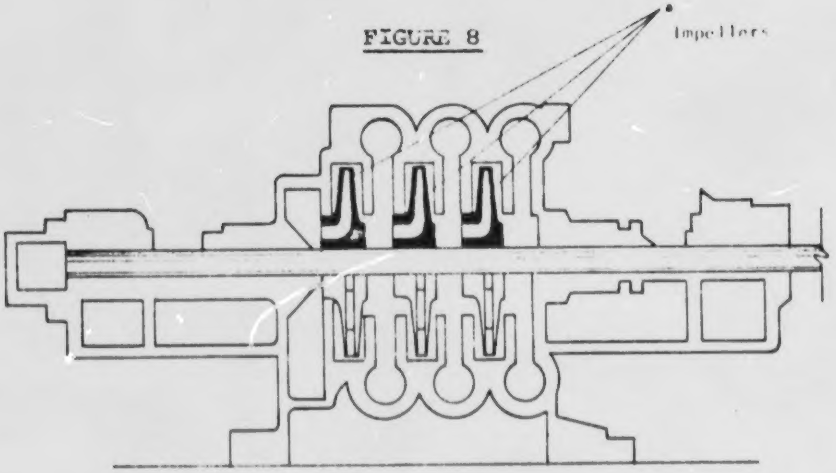
The turbine pump uses a circular casing with built-in diffusing vanes to convert velocity energy (head) to pressure energy (head) more efficiently than the common centrifugal pump thus providing a higher pressure. (Figure 9)

The deep-well turbine (submersible) pump is generally a multistage vertical turbine pump that allows it and the motor to be submerged. Therefore there is no suction lift.

Air pockets can affect the operation of centrifugal pumps. The output of the pump could be reduced by changing the suction head to the pump, particularly if the air pocket works its way to the pump unit. To prevent this likelihood, the pump should be set so there is positive head to the suction line of 1" in each 15 ft. This will prevent the build up of air pockets.

Water hammer is the oscillation of water pressure in a closed conduit that is the result of sudden changes in the velocity of flow. This can be caused by rapidly closing a valve or abruptly shutting down a pump. The pressure waves coming from this phenomena causes fluctuations in pressure and can be dangerous. In large systems special valves can be installed to prevent or reduce the impact of water hammer.

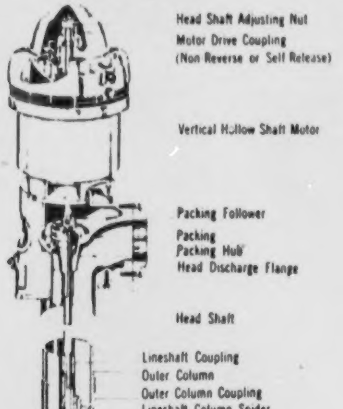
FIGURE 8



Multistage Centrifugal Pump

(Source: "Water Distribution Operator Training Handbook. 1976. AWWA)

FIGURE 9


Head Shaft Adjusting Nut
Motor Drive Coupling
(Non Reverse or Self Release)
Vertical Hollow Shaft Motor
Packing Follower
Packing
Packing Hub
Head Discharge Flange
Head Shaft
Lineshaft Coupling
Outer Column
Outer Column Coupling
Lineshaft Column Spider
Lineshaft Bearing
Lineshaft Sleeve
Lineshaft
Discharge Stage Sand Cap
Bowl Assembly Discharge Flange
Discharge Stage Bearing
Discharge Stage
Bowl Shaft
Bowl (Stage) Bearing
Bowl (Impeller Stage)
Impeller
Impeller Taper Lock
Bearing Stage Sand Cap
Bearing Stage
Bearing Stage Bearing
Bowl Assembly Suction Flange
Strainer

Turbine Pump

PARTS OF CENTRIFUGAL PUMPS

Impeller - A propeller like device that picks up the water as it moves along the pump shaft and converts the rotary motion of the motor and shaft to velocity of water. This results in an efficient change of flow direction from axial to radial. As the water is forced outward into the pump casing, both pressure energy (head) and velocity energy (head) increase. Most impellers are made of bronze. Some however, are made of cast iron or stainless steel.

Case - The casing houses the impeller. It is designed to take the velocity energy (head) generated by the water leaving the impeller and convert it to pressure energy (head). This is done by designing the case in the form of a smooth volute of spiral around the impeller. Diffuser or turbine type pump cases have vanes located radially around the impeller. The casing is usually circular instead of the volute type. Cast iron is the most common material used to make casings.

Shaft - The pump shaft is responsible for transferring the power from the prime mover to the impeller. Usually, the shaft is made of steel. The impeller is generally attached to the shaft with a key and tight shrink fit. Although it can be attached by threaded and sweated linkage.

Packing glands (stuffing boxes) - The packing glands are located at the point where the shaft protrudes through the case of the pump keeping the air out and the water in the case. This area can be subject to either suction lift (air can enter pump) or suction head pressure (water leaks out along shaft). Thus it is necessary to have a seal wherever the pump shaft protrudes through the case. The gland area of the case is designed so that several separate rings of graphite impregnated asbestoes material can be compressed against the shaft thus stopping air or water leakage. The asbestoes material is used due to the heat generated between the packing rings and the turning pump shaft. The graphite acts as a lubricant.

Most pump manufacturers will recommend a mechanical seal under high suction head (60 psig or more) conditions. The major disadvantages of the mechanical seal are relative difficulty of replacement compared to packing rings and considerable leakage when a seal fails. Excessive wear of packing glands can normally be detected before major leakage begins.

Lantern ring - If the packing along the shaft is not sufficient under suction lift conditions, air will enter the water stream. To insure against leakage, a lantern ring is inserted in place of one of the center packing rings. The ring has radial holes that allow the formation of a water seal which cools, reduces wear, and increases efficiency of the packing glands.

Shaft sleeve - The sleeves fit around the shaft and provide protection for it at points of wear. This prevents the shaft itself from wearing. When the sleeves show wear, they can be replaced. Shaft sleeves are located generally wherever you have bearings or packing glands. Usually sleeves are made of bronze alloy because of its resistance to the corrosive effects of water.

Wear rings - A wear ring is located both in the case and on the impeller of most centrifugal pumps. The rotating impeller ring and the stationary case ring effectively restricts leakage from impeller discharge to suction. Inexpensive pumps do not have separate wear rings as such, but the case and impeller are machined to prevent this leakage. Most pump manufacturers produce replacement impeller and case rings.

Bearings - Bearings in most pumps are of the ball-type radial and thrust design. They support and allow the shaft to turn. Grease or oil are used for lubrication. They are easily maintained or replaced.

SELF-TEST

1. Name the four main types of centrifugal pumps.	a. volute b. turbine c. multistage d. deep well-turbine
2. The __________ of a pump is designed to take the velocity energy (head) and convert it to pressure energy (head).	case
3. The impeller is attached to the _________.	shaft
4. The point where the shaft extends through the case of the pump is called __________ _________.	packing glands
5. The shaft sleeves provide protection for the __________.	shaft
6. _________ support and allow the shaft to turn.	Bearings

OPERATION AND MAINTENANCE

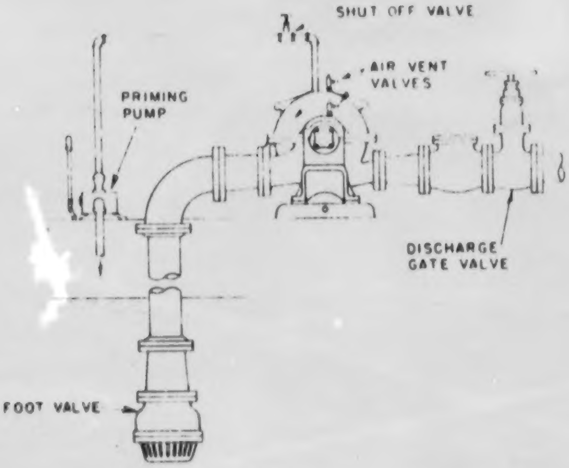
It is essential that an operator have a complete understanding of the pump construction for proper operation and maintenance.

When starting a pump several items should be checked:

1. Bearing lubricated - oil or grease can be used but should not be overdone. Excessive grease can cause a bearing to overheat. Too much oil can cause foaming. Follow the manufacturers instructions.
2. Open suction and discharge valves.
3. Prime or vent the pumps (Figure 10). The impeller must be submerged in water before the centrifugal pump can operate. The case is filled with water so that the pump can develop a suction at the eye of the pump. Pumps may have a priming tank or auxiliary water supply where water can be admitted into the pump case and the air discharged. Also, a foot valve can be installed that will keep the pump and the suction line full of water. However, if the pump is located below the water level so there is pressure on the suction side, priming is unnecessary.
4. Start the pump.

FIGURE 10

Priming-Pump Installation



(Source: "Water Distribution Operator Training Handbook." 1976, AWWA.)

5. Keep check on temperature of bearings and packing gland until a constant temperature is reached. Adjust as necessary. Care should be taken and not tighten the packing too tight. Tighten with fingers instead of a wrench when possible. If shaft or packing box leaks excessively replace them.

6. If the pump is powered with an electric motor, the running amperage should be checked and any abnormal demands investigated.

Routine checks (daily if necessary) should be made on pumps that are running continuously. The folowing items should be examined.

1. Pump Pressure and Output - check and record.
2. Bearings - check for heat and noise
3. Motors - check operating speed
4. Control Equipment - check for cleanliness and condition
5. Pump Operation - check for vibration and noise
6. Packing Glands - if excessive leakage, then replace. Do not put new packing on top of old. To insure against contamination when packing a pump, there should always be water running out of the packing gland to provide positive pressure at the point of packing. There should be a very slow drip of water coming through the packing.
7. Shaft Sleeves, Shaft Couplings, and Wearing Rings - replace when worn or loss of efficiency will result.
8. Alignment - check to guard against unnecessary and faster than normal bearing and coupling wear. Check when unit is cold and again at operating temperature. New installations can change alignment quickly, therefore it should be examined frequently until stable operation is achieved. Consult manufacturer's specifications for proper procedure and tolerances.

The following chart, originally published in the Allis-Chalmers publication "General Pump Instructions", is an excellent guide for trouble shooting pumps and pump motors. Some of the common symptoms of pump problems are given along with their causes and cures. (Source: Opflow 4(4): 4-5. AWWA).

NO LIQUID DELIVERED

	Cause	Cure
1.	Lack of prime.	Fill pump and suction pipe completely with liquid.
2.	Loss of prime.	Check for leaks in suction pipe joints and fittings; vent casing to remove accumulated air.
3.	Suction lift too high.	If no obstruction at inlet, check for pipe friction losses. However, static lift may be too great. Measure with mercury column or vacuum gage while pump is operating. If static lift is too high, liquid to be pumped must be raised or pump lowered.
4.	Discharge head too high.	Check pipe friction losses. Large piping may correct condition. Check that valves are wide open.
5.	Speed too low.	Check whether motor is directly across-the-line and receiving full voltage. Or, frequency may be too low; motor may have an open phase.
6.	Wrong direction of rotation.	Check motor rotation with directional arrow on pump casing.
7.	Impeller completely plugged.	Dismantle pump and clean impeller.

NOT ENOUGH LIQUID DELIVERED

	Cause	Cure
8.	Air leaks in suction piping.	Test flanges for leakage with flame or match.
9.	Air leaks in stuffing box.	Increase seal lubricant pressure to above atmosphere.
10.	Speed too low.	See Item 5.
11.	Discharge head too high.	See Item 4.
12.	Suction lift too high.	See Item 3.
13.	Impeller partially plugged.	See Item 7.
14.	Cavitation; insufficient net positive suction head (depending on installation).	A. Increase positive suction head on pump by lowering pump. B. Sub-cool suction piping at inlet to lower entering liquid temperature. C. Pressurize suction vessel.

15.	Defective impeller.	Inspect impeller, bearings, and shaft. Replace if damaged or if vane sections are badly eroded.
16.	Defective packing.	Replace packing and sleeves if badly worn.
17.	Foot valve too small or partially obstructed.	Area through ports of valve should be at least as large as area of suction pipe-preferably 1½ times. If strainer is used, net clear area should be 3-4 times area of suction pipe.
18.	Suction inlet not immersed deep enough.	If inlet cannot be lowered, or if eddies through which air is sucked persist when it is lowered, then chain a board to suction pipe. It will be drawn into eddies, smothering the vortex.
19.	Wrong direction of rotation.	Symptoms are an overloaded drive and about 1/3 rated capacity from pump. Compare rotation of motor with directional arrow on pump casing.
20.	Too small impeller diameter. (Probable cause if none of previous causes.)	Check with manufacturer to see if a larger impeller can be used; otherwise, cut pipe losses or increase speed, or both, as needed. Be careful not to seriously overload drive.

NOT ENOUGH PRESSURE

	Cause	Cure
21.	Speed too low.	See Item 5.
22.	Air leaks in suction piping.	See Item 8.
23.	Mechanical defects.	See Items 15, 16 and 17.
24.	Obstruction in liquid passage.	Dismantle pump and inspect passages of impeller and casing. Remove obstruction.
25.	Air or gases in liquid. (Test in laboratory, reducing pressure on liquid to pressure in suction line. Watch for bubbles.)	May be possible to over rate the pump to a point where it will provide adequate pressure despite condition. Better to provide gas separation chamber on suction line near pump and periodically exhaust accumulated gas. (See Item 14.)
26.	Too small impeller diameter. (Probable cause if none of previous causes.)	See Item 20.

PUMP OPERATES FOR SHORT TIME, THEN STOPS PUMPING

	Cause	Cure
27.	Incomplete priming.	Free pump, piping, and valves of all air. If high points in suction line prevent this, then they need to be corrected.
28.	Suction lift too high.	See Item 3.
29.	Air leaks in suction piping.	See Item 8.
30.	Air leaks in stuffing box.	See Item 9.
31.	Air or gases in liquid.	See Item 25.

PUMP REQUIRES TOO MUCH POWER

	Cause	Cure
32.	Head lower than rating; thereby pumping too much liquid.	Machine the impeller's O.D. to size advised by manufacturer.
33.	Cavitation.	See Item 14.
34.	Mechanical defects.	See Items 15, 16, and 17.
35.	Suction inlet not immersed enough.	See Item 18.
36.	Wrong direction of rotation.	See Item 6.
37.	Stuffing boxes too tight.	Release gland pressure. Tighten reasonably. If sealing liquid does not flow while pump operates, replace packing. If packing is wearing too quickly, replace scored shaft sleeves and keep liquid seeping for lubrication.
38.	Casing distorted by excessive strains from suction or discharge piping.	Check alignment. Examine pump for friction between impeller and casing. Replace damaged parts.
39.	Shaft bent due to damage; improper shipment, operation, or overhaul.	Check deflection of rotor by turning on bearing journals. Total indicator runout should not exceed 0.002 in. (0.05 mm) on shaft and 0.004 in. (0.10mm) on impeller wearing surface.
40.	Mechanical failure of critical pump parts.	Check bearings and impeller for damage. Any irregularity in these parts will cause a drag on the shaft.
41.	Misalignment.	Realign pump and driver.

42.	Speed may be too high (brake horsepower of pump varies as the cube of the speed; therefore, any increase in speed means considerable increase in power demand.)	Check voltage on motor.
43.	Electrical defects.	The voltage and frequency of the electrical current may be lower than that for which the motor was built; or there may be defects in the motor. The motor may not be ventilated properly due to a poor location.
44.	Mechanical defects in turbine, engine, or other type of drive exclusive of motor.	If trouble cannot be located, consult the manufacturer.

SELF-TEST

1. List the items you should check when starting a motor for the first time.	a. Bearing lubrication b. open valves c. prime pump d. check temperature e. electric motor
2. Excessive grease results in bearings being __________.	overheated
3. List the items you should inspect on a routine basis.	pump pressure and output bearings motors control equipment pump operation packing glands shaft sleeves couplings wearing rings alignment

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY pp. 232-233.
2. Manual of Water Utility Operations, Texas Water Utilities Association, Austin, TX Chapter 13.
3. Basic Water Treatment Operator's Manual, AWWA. Manual M18, AWWA, Denver, CO Chapter 13.
4. Water Distribution Training Course, AWWA. Manual M8, AWWA, Denver, CO Chapter 3.
5. Water Distribution Operator Training Handbook, AWWA, Denver, CO Chapter 11.

POST-EVALUATION (10 pts. each question)

1. True or False (2 pts. each)
   a. The most commonly used pump today is the centrifugal pump.
   b. The modern centrifugal pump has a lift capacity in excess of 34 ft. at sea level.
   c. Centrifugal pumps are self priming if the water is under a positive head.
   d. Duplicate pumps should be installed for more efficient operation of the treatment plant.
   e. The water horsepower will always be smaller than the brake horsepower of a pump.

2. Determine the efficiency of a pump operating under the following conditions:

   Operating head = 45 ft.
   Pump capacity = 600 gpm
   Brake horsepower = 20

3. __________ centrifugal pumps have two or more impellers on the same shaft.

4. What effect will an air pocket have on the capacity of a centrifugal pump?

5. Define: (2 pts. each)
   Suction lift
   Head
   Capacity
   Centrifugal pump
   Pump efficiency

6. When is a centrifugal pump self priming?

7. What is the function of a foot valve?

8. In practice, what is the maximum suction lift for a centrifugal pump?

9. How can you insure against contamination when packing a pump?

10. Matching (1 pt. each)

1.	Shaft _____	a.	Power source for operating pump.
2.	Impeller _____	b.	Converts water velocity to water pressure.
3.	Static suction head _____	c.	A type of electric motor.
4.	Squirrel cage _____	d.	Keeps air out and water in case.
5.	Friction loss _____	e.	The power that is applied by the driver to the pump shaft.
6.	Wear ring _____	f.	Loss of energy due to friction of water moving through the pipe.
7.	Case _____	g.	Supports, aligns and rotates impeller.

8. Brake horsepower _____

9. Packing glands _____

10. Prime mover _____

h. Converts rotary motion of the motor and shaft to water velocity.

i. The vertical distance from the water supply level to the pump centerline with the pump below the supply level.

j. Prevents circulation of water between impeller suction and discharge.

ANSWERS

1. a. T
   b. F
   c. T
   d. T
   e. T

2. 34%

3. Multistage

4. Decrease the capacity.

5. Suction Lift: The sum of the static suction lift, the suction friction head and entrance loss in the suction pipe. This generally results in a negative pressure condition at the suction nozzle.
   Head: A measure of water pressure (feet of liquid; pounds per square inch; or inches of mercury).
   Capacity: Amount of water pump is capable of moving for a specific internal of time under a given set of conditions. This is usually expressed as gallons per minute or million gallons per day.
   Centrifugal pump: A device that pressurizes a liquid by centrifugal force generated by a wheel called an impeller, revolving in a tight casing.
   Pump efficiency: The ability of a pump to convert brake horsepower to water horsepower expressed as a percent.

6. When you have the source of supply located above the center line of the pump (suction or positive head).

7. The foot valve holds the water in the pump and suction line making it unnecessary to prime the pump.

8. Approximately 20 ft.

9. Maintain a positive pressure at the point of packing allowing water to run out of the packing gland at all times.

10. 1. Shaft - g
    2. Impeller - h
    3. Static Suction head - i
    4. Squirrel cage - c
    5. Friction head - f
    6. Wear ring - j
    7. Case - b
    8. Brake horsepower - e
    9. Packing glands - d
    10. Prime mover - a

MODULE 12

SELF-INSTRUCTIONAL

James H. Shaddy - NMSU

CROSS CONNECTIONS

PREREQUISITES:
- Module One - Basic Mathematics
- Module Six - Hydraulics
- Module Eight - Plant Operations
- Module Fourteen - Safety

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. True or False (20 pts. total; 5 pts. per question)
   a. Serious illness and even death have been reported to be caused by cross connections.
   b. There are no laws that deal with cross connections between a system supplying potable water and a system furnishing non-potable water.
   c. One reason that cross connections exist is that the people installing the plumbing are unaware of the dangers of cross connections.
   d. Air gap separation is a means of preventing either blackflow or backsiphonage.
2. What are the two basic types of cross connections? (20 pts.)
3. Explain how backflow occurs. (20 pts.)
4. Name the two main types of backsiphonage preventers. (20 pts.)
5. What is a cross connection? (20 pts.)

ANSWERS

1. a. T
   b. F
   c. T
   d. T
2. Backflow (direct) and Backsiphonage (indirect)
3. Backflow is a result of a reversed flow of the liquid due to back pressure other than siphonic action.
4. Non-pressure (atmospheric) vacuum breaker and pressure vacuum breaker.
5. A link that either permanently or temporarily connects a source of non-potable water (unsafe) or contaminate with a potable water (safe) supply system.

INTRODUCTION

Cross connections that connect a potable water supply with a non-potable supply are a threat to public health. This module will present basic information on the types of cross connections, recognition of actual and potential cross connections, and prevention of cross connections. Some of the material used in this module was taken from the publication "Cross Connection Control Manual" published by the Environmental Protection Agency. In addition, information taken from "Cross Connections and Backflow Prevention", 2nd edition, Copyright 1974, has been reprinted with permission granted by the American Water Works Association, Denver, Colorado.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the following concepts:

1. Types of cross connections
2. Identification of potential and actual cross connections
3. Cross connection control and prevention

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer was correct. If you can answer all the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

CROSS CONNECTIONS

A cross connection is a link that either permanently or temporarily connects a source of pollution with a potable water supply system. Usually the polluted water enters the potable water system when the pressure of the polluted source exceeds the pressure of the potable source resulting in a reversal of flow. This is commonly known as either backsiphonage or backflow depending on the circumstances.

Cross connections can provide a major threat to the public health if they are undetected or inadequately maintained.

Many instances of serious illness and even death have been reported to be due to cross connections. For example, during the 1969 season most of the members and coaches of a collage football team contracted infectious hepatitis. The water supply on the practice field was found to be the cause. A drinking fountain and irrigation system for the field were on the same line. A heavy fire demand generated a negative pressure in the waterlines thus causing contaminated surface water around the sprinklers to be siphoned into the potable water lines. Players and coaches after drinking from the fountain, became ill. All remaining games had to be cancelled.

Another illustration involving the contamination of a water supply came about from a truck obtaining water from a city water supply. A contractor using a tank truck equiped with a device that allowed spraying, connected to a fire hydrant to fill the truck with water. At the same time, the water was being mixed with fertilizer, grass seed and woodpulp and applied to the grounds of a subdivision. A high pressure pump was used to spray the mixture onto the ground. However, the woodpulp plugged one of the lines while the pump kept running. This created a very high pressure in the tank. Consequently, with the pressure higher in the tank than in the water system, the mixture was forced into the water system. Several people in the subdivision became ill. Soon the contamination was discovered, the lines flushed and disinfected, and the danger eliminated.

The foregoing two examples serve to illustrate the importance of preventing, detecting, or properly maintaining cross connections within a community.

The water-treatment plant operator must be aware of and correct any cross connections within his plant. This can be accomplished by frequent survey checks. Cross connections could exist in raw water pumps, chemical feed machines, solution tanks, laboratory and other places. It is specifically stated in the Occupational Safety and Health Act of 1970 (OSHA) that "there shall be no cross connection, open or potential, between a system furnishing potable water and a system furnishing non-potable water. Construction shall be such as to prevent backflow of contaminated water into a potable water system."

In addition, it is stated in the Rules of the Department of Natural Resources, Division 60 - Public Water Supply, Chapter 2 - Public Water Supply, 10 CSR 60 - 2.010, section 11, that "no physical connections shall be permitted between any public water supply either through cross connections, auxiliary intakes, or bypasses and that of any other supply, except with a water supply approved by the Department of Natural Resources.

Some cross connections are obvious and others are not. Reversal of pressure in water is unusual but it does happen. Within a single plumbing system, the probability of experiencing a problem with contaminating a drinking water supply is quite small. However, when you consider several systems together, the probability becomes much larger.

Cross connections exist primarily for three reasons:

1. Ignorance - the people installing the plumbing are unaware of the dangers of cross connections.
2. Convenience - the easiest installation method is selected without thought to the problem of contamination.
3. Inadequate protection - rely on single valve or other devices that are not sufficient.

The courts of the United States have placed the responsibility of eliminating cross connections in the public water supply directly on the water purveyor(supplier). The purveyor can be held responsible for another authority's acts or lack of action should negligence be shown. The best protection and the only defense the courts have recognized with favor, has been evidence to show that the water purveyor had, 1) acted in good faith, 2) adopted an acceptable cross connection control program that was enforced, and 3) prosecuted violators.

SELF-TEST

1. Define cross connection.	A link that either permanently or temporarily connects a source of contamination with a potable water supply system.
2. Why do cross connections exist in the first place?	Ignorance - people are unaware of the danger. Convenience - people use the easiest installation procedures available without thought to contamination. Inadequate protection use inappropriate control devices.
3. True or False. The water supplier is not responsible for removal of cross connections in the water system.	False

TYPES OF CROSS CONNECTIONS

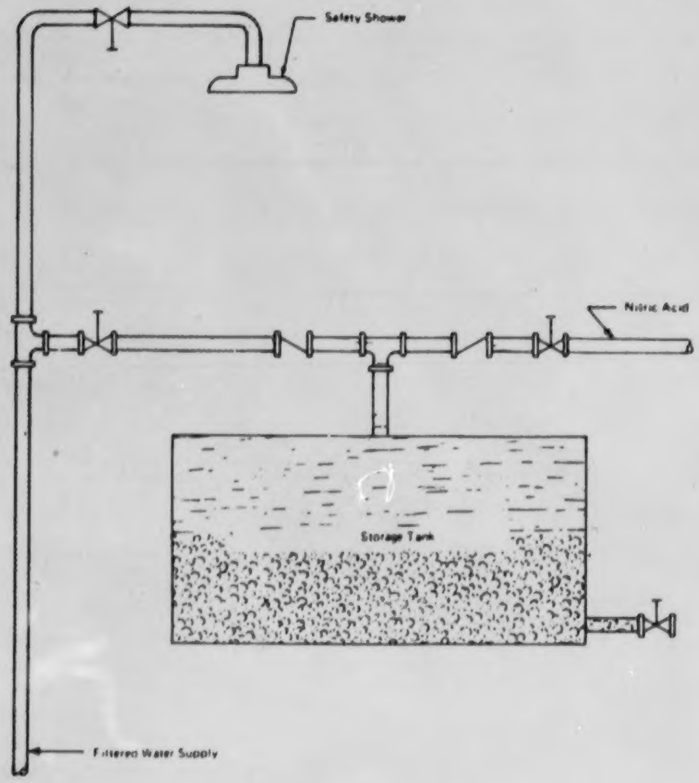
There are basically two types of cross connections that would be found in most water systems, backflow (direct connections) and back-siphonage (indirect connections, submerged inlets).

Usually backflow is referred to as reversed flow due to back pressure other than siphonic action. A typical example of this is illustrated in Figure 1. In this case, an acid tank is attached directly to a potable water supply system. In addition, a nitric acid line is attached to the same tank. Two metal-seated check valves are located between the two fluids. If the pressure is lowered in the water supply line, the acid could enter the water supply and result in serious consequences. Even if the pressure is normally high enough to prevent the diluted acid from entering the water system, conditions can be reversed through fire demand, accident, or mechanical failure of pumping equipment.

Another example of a backflow problem is illustrated in Figure 2. In this system, the sprinkler is normally supplied from a nearby lake using a high-pressure pump (B). There is only a single valve between the public, potable water supply and the fire sprinkler system of the plant (A). When the valve is left open, untreated, potentially polluted water can be pumped directly into the public water supply.

If we define cross connections loosely, Figure 3 is also a backflow example. The household water system which is served by the city main (A) is also connected by means of a valve to a well supply (B), that is polluted by a septic tank. The purpose of this may be to prime the well pump. The well is used for sprinkling the lawn. Now, if the valve is left open or is leaky and the city water pressure falls below that of the well pump then the contaminated well water will be pumped into the city water supply.

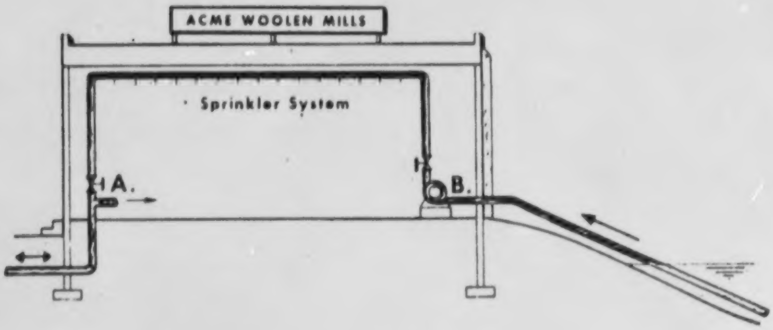
FIGURE 1


Safety Shower
Nitric Acid
Storage Tank
Filtered Water Supply

Backflow Example

(Source: "Cross Connections & Backflow Prevention". 1974. 2nd Edition AWWA).

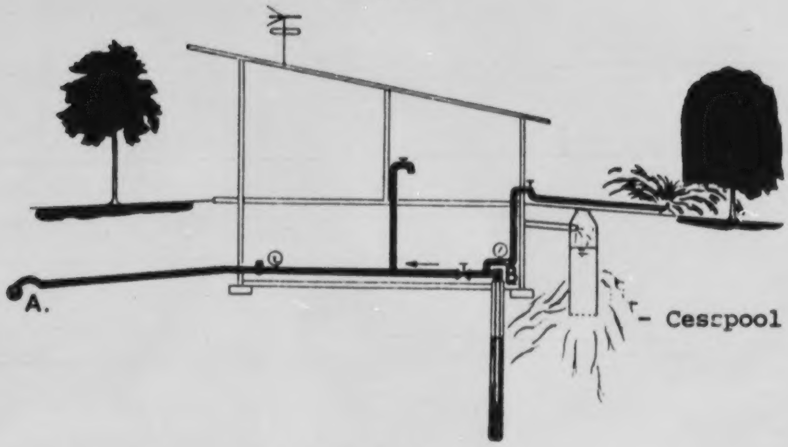
FIGURE 2


ACME WOOLEN MILLS
Sprinkler System
A.
B.

Backflow Example

(Source: "Cross Connection Control Manual". 1973. U.S. Environmental Protection Agency).

FIGURE 3

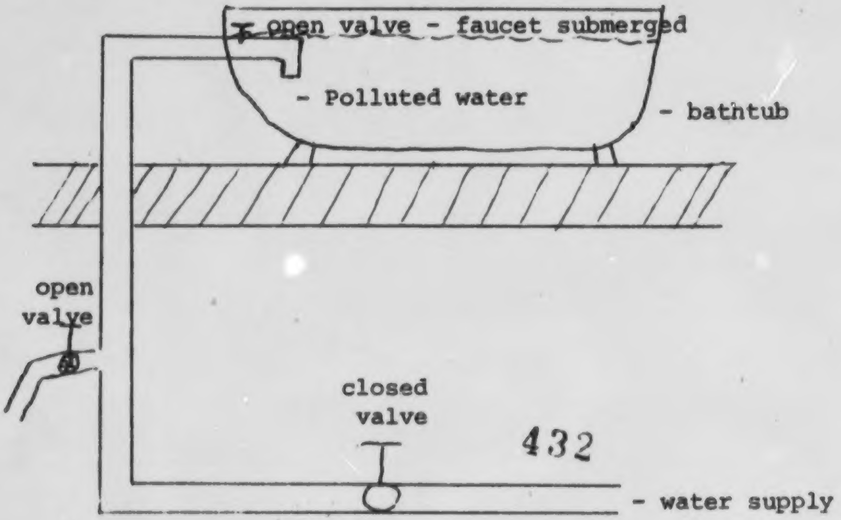


Backflow Example

(Source: "Cross Connection Control Manual". 1973. U.S. Environmental Protection Agency).

Backsiphonage on the otherhand results from negative pressure in the distributing pipes of a potable water supply. There are several potential sources of negative pressure, i.e. low pressure in community water system, break in the water main, fire demands and usage of water exceeding the capacity of the system. None of these should be tolerated. Figure 4 shows how the backsiphoning principle can be hazardous in a plumbing system where you have a difference in water levels at two separate points within the system.

FIGURE 4


open valve - faucet submerged
- Polluted water
- bathtub
open valve
closed valve
- water supply

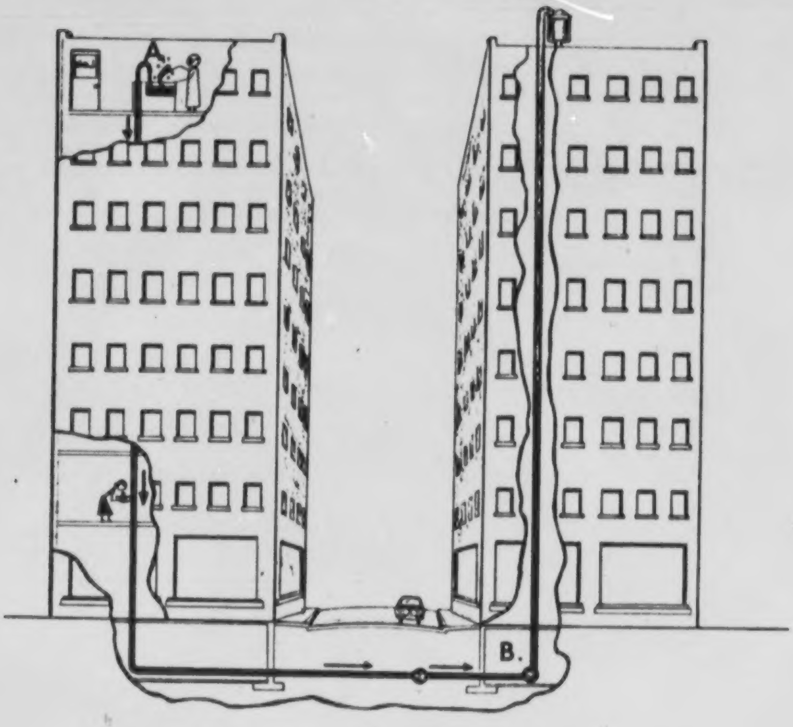
Backsiphonage in a Plumbing System

(Adapted from: "Cross Connection Control Manual." 1973. U.S. Environmental Protection Agency).

If the water supply valve is closed, the pressure in the line to the bathtub is greater than the pressure in the line supplying the faucet. Consequently, flow of polluted water will occur as a result of backsiphonage from the bathtub to the open faucet.

Another type of backsiphonage is illustrated in Figure 5. Two tall buildings are connected to the same water main. Since the water main often doesn't have satisfactory pressure, the building on the right installed a booster pump. The booster pump starts pumping when the pressure in the main becomes inadequate. This produces a negative pressure in the main. In the opposite building a rubber hose is submerged in a laboratory sink. Because of the negative pressure in the main, a reversal of flow begins to occur. Contaminated water from the sink can enter the potable water supply.

FIGURE 5



Backsiphonage Example

(Source: "Cross Connection Control Manual". 1973. U.S. Environmental Protection Agency).

There are basically two types of connecting links between the potable supply and a source of the contaminated water or toxic substances. They are the solid pipe or direct connection and the submerged inlet. Several examples are listed in Table 1. Another less common link may occur between the public supply and an individual homeowner.

TABLE 1

Fixtures with Direct Connections

Description
Air conditioning, air washer
Air conditioning, chilled water
Air conditioning, condenser water
Air line
Aspirator, laboratory
Aspirator, medical
Aspirator, weedicide and fertilizer sprayer
Autoclave and sterilizer
Auxiliary system, industrial
Auxiliary system, surface water
Auxiliary system, unapproved well supply
Boiler system
Chemical feeder, pot-type
Chlorinator
Coffee urn
Cooling system
Dishwasher
Fire standpipe or sprinkler system
Fountain, ornamental
Hydraulic equipment
Laboratory equipment
Lubrication, pump bearings
Photostat equipment
Plumber's friend, pneumatic
Pump, pneumatic ejector
Pump, prime line
Pump, water operated ejector
Sewer, sanitary
Sewer, storm
Swimming pool

Fixtures with Submerged Inlets

Description
Baptismal fount
Bathtub
Bedpan washer, flushing rim
Bidet
Brine tank
Cooling tower
Cuspidor
Drinking fountain
Floor drain, flushing rim
Garbage can washer
Ice maker
Laboratory sink, serrated nozzle
Laundry machine
Lavatory
Lawn sprinkler system
Photo laboratory sink
Sewer flushing manhole
Slop sink, flushing rim
Slop sink, threaded supply
Steam table
Urinal, siphon jet blowout
Vegetable peeler
Water closet, flush tank, ball cock
Water closet, flush valve, siphon jet

Partial List of Plumbing Hazards

(Source: "Cross Connection Control Manual," 1973. U.S. Environmental Protection Agency).

SELF-TEST

1. The two main types of cross connections are ________ and ________.	backflow backsiphonage
2. What causes backsiphonage.	Negative pressure in the water supply system resulting in a siphonic action.
3. Name two causes of negative pressure within a water distribution system.	Fire demand Break in water main
4. What causes backflow?	Reversed flow of the water due to back pressure other than siphonic action.

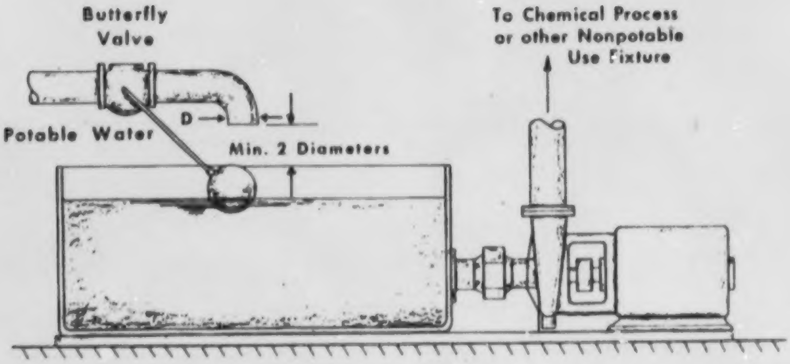
BACKSIPHONAGE AND BACKFLOW PREVENTERS

When possible, the complete removal of the cross connection is desirable because it eliminates the potential failure of a mechanical device. When removal is not feasible, then the proper cross connection control device should be installed. There are no cases where a cross connection cannot be removed or corrected.

Air gap separation is probably the oldest method of preventing cross connections resulting from either backflow or backsiphonage. (Figures 6 and 7). In order for the air gap method to be completely reliable the gap should be twice the diameter of the effective opening of the supply pipe. However, bypassing is easily accomplished and must be prevented.

There are two types of vacuum breakers that are commonly used to prevent backsiphonage, pressure and non-pressure (atmospheric). These vacuum breakers are designed to admit atmospheric pressure into a piping system between a source of contamination and potable water. They should not be installed where backpressure may occur. A nonpressure vacuum breaker (Figure 8) should be installed on the atmospheric side of a valve. It will operate each time the valve is used. In Figure 8(1) the flow of water is downward. The disc is in place preventing water from escaping the pipe. When a negative pressure (vacuum) develops in the supply line, atmospheric pressure will force the disc into the horizontal position thus blocking the supply line. This admits air and prevents backsiphonage (Figure 8 (2) and (3))

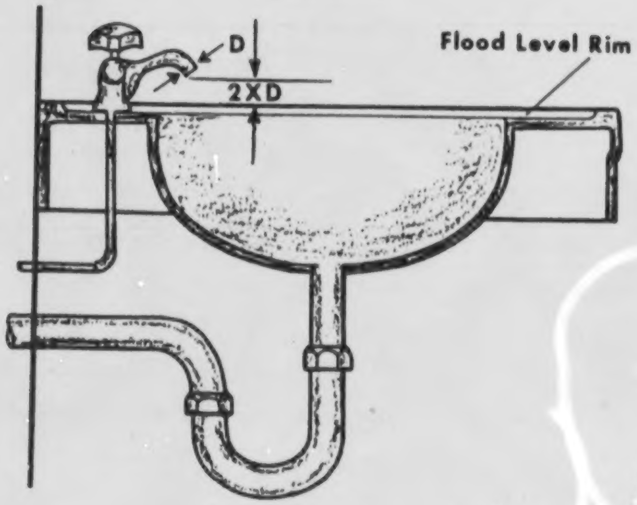
FIGURE 6



Surge Tank and Booster Pump with Air Gap

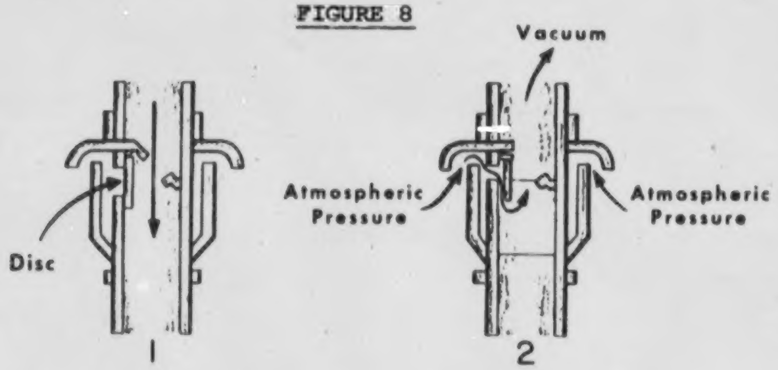
(Source: "Cross Connections Control Manual". 1973. U.S. Environmental Protection Agency).

FIGURE 7


D
2XD
Flood Level Rim

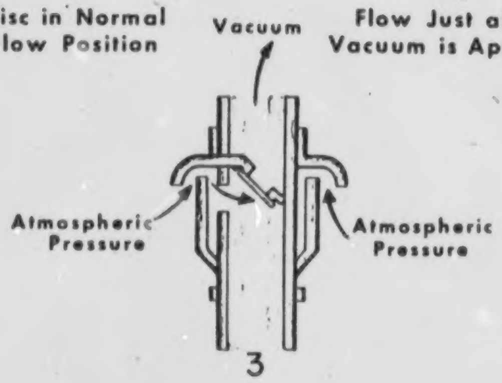
Air Gap on Lavatory
(Source: "Cross Connection Control Manual". 1973. U.S. Environmental Protection Agency).

FIGURE 8


Vacuum
Disc
Atmospheric Pressure
Atmospheric Pressure
1
2

Disc in Normal Flow Position

Flow Just after Vacuum is Applied


Vacuum
Atmospheric Pressure
Atmospheric Pressure
3

Disc in Vacuum Breaking Position

Operation of a Nonpressure (Atmospheric) Vacuum Breaker

(Source: "Cross Connection Control Manual". 1973. U.S. Environmental Protection Agency).

A pressure-type vacuum breaker is installed in pressurized systems and operates only when a vacuum occurs (Figure 9). This breaker is designed to operate under pressure and is usually spring loaded. However, it does not completely protect the system and could, with certain piping arrangements allow backsiphonage into the potable water system.

The prevention of backflow is usually accomplished by either a reduced pressure zone backflow preventer or a double check valve assembly. In the reduced pressure zone backflow preventer (Figure 10) the pressure differential relief valve (3) drains to the atmosphere allowing the zone between the two spring loaded check valves (1 and 2) to be maintained at a pressure less than that of the supply. This represents the hydraulic principle that water will not flow from a zone of lower pressure to a zone of higher pressure. The system operates by the relief valve (3) being held in the closed position when the pressure on the supply side is greater (usually a predetermined amount) than the pressure in the zone between the two check valves (1 and 2). If the supply side loses pressure, the relief valve opens and the intermediate zone discharges to the atmosphere. If pressure on the discharge side becomes higher than the pressure of the supply the second check valve should close. Should the second check valve malfunction, the intermediate zone will discharge to the atmosphere. If one or both of the check valves or relief valve malfunctions, there will be a discharge of water from the relief port.

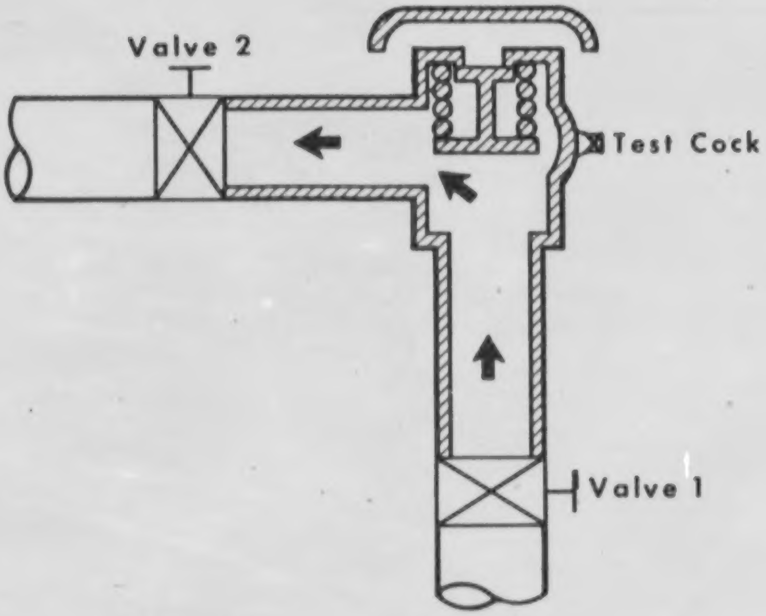
Among other methods of preventing backflow, the single check valve, plain double check valve assembly, the swivel connection and the barometric loop, the double check - double gate valve assembly (Figure 11) have proved useful. If they are properly maintained, they are generally reliable for intermediate degrees of hazzard. This particular backflow preventer has the advantage of low head loss. But you do not know when they are malfunctioning. Therefore, it is essential that a regular inspection program (yearly) be maintained to ensure safety.

Table 2 presents a summary of the various types of cross connections, hazzards and recommended types of prevention devices.

It should be noted that vacuum breakers and check valves should not be relied upon for absolute protection of the public water supply from a substance that is a health hazard. The reduced pressure zone backflow preventer is the best device to use to protect the potable water supply from contamination. However, the owners of buildings, i.e. hospitals, factories, etc. should be made aware that to provide necessary protection for their workers in the buildings, air gaps and vacuum breakers must be used.

For proper maintenance and testing of backflow preventers you should consult the proper manuals listed in Suggested Readings Section.

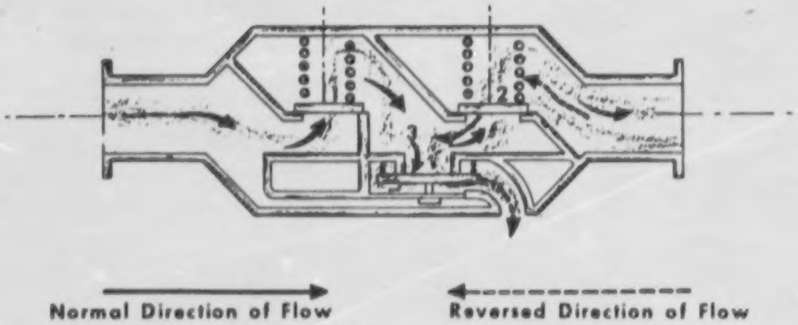
FIGURE 9


Valve 2
Test Cock
Valve 1

A Pressure-Type Vacuum Breaker Installation

(Source: "Cross Connection Control Manual". 1973. U.S. Environmental Protection Agency).

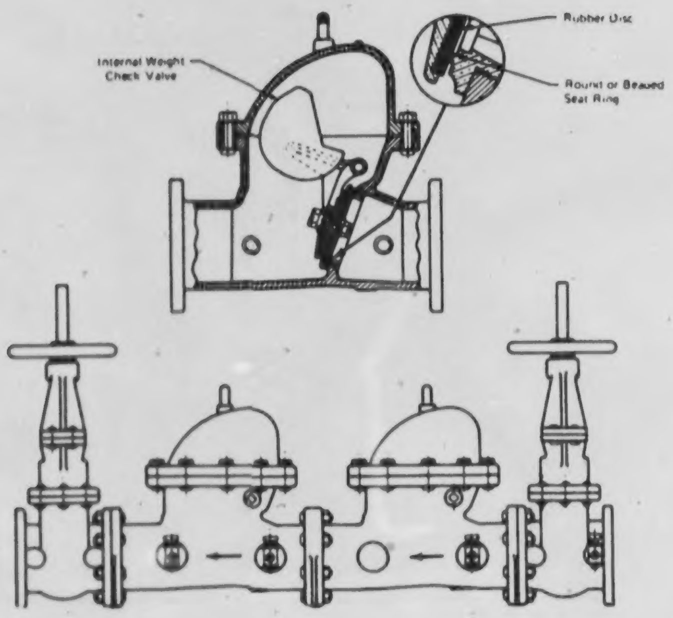
FIGURE 10


Normal Direction of Flow
Reversed Direction of Flow

Operation of a Reduced Pressure Zone Backflow Preventer

(Source: "Cross Connection Control Manual". 1973. U.S. Environmental Protection Agency).

FIGURE 11


Internal Weight Check Valve
Rubber Disc
Round or Beaded Seat Ring

An Example of a Double Check - Double Gate Valve Assembly

(Source: "Cross Connections & Backflow Prevention." 1974. 2nd Edition. AWWA).

TABLE 2

	Degree of Hazard			Recommended Device				
					For Backflow		For Backsiphonage	
Direct or Indirect Water Connections	Severe	Moderate	Minor	Air Gap*	Reduced Pressure Device	Double Check-Valve Assembly	Pressure Vacuum Breaker	Atmospheric Vacuum Breaker
I. Subject to backpressure:								
A. Pumps, tanks, and lines handling:								
1. Sewage and lethal substances	x			x	x			
2. Toxic substances	x			x	x			
3. Nontoxic substances		x			x	x		
B. Water connection to steam and steam boiler:								
1. Boiler or steam connection to toxic substances	x			x	x			
2. Boiler or steam connection to nontoxic substances (boiler blowoff through approved gap)		x		x	x	x		
II. Not subject to backpressure:								
A. Sewer-connected waste line (not subject to waste stoppages)	x			x	x		x	x
B. Low inlets to receptacles containing toxic substances	x			x	x		x	x
C. Low inlets to receptacles containing nontoxic substances		x		x	x	x	x	x
D. Low inlets into domestic water tanks			x		Each case should be treated separately			
E. Lawn sprinkler systems	x			x	x		x	x
F. Coils or jackets used as heat exchangers in compressors, degreasers, etc.:								
1. In sewer lines	x			x	x			
2. In lines carrying toxic substances	x			x	x		x	x
3. In lines carrying nontoxic substances		x			Each case should be treated separately			
G. Flush valve toilets	x			x	x			
H. Toilet and urinal tanks		x		x				x
I. Trough urinals		x						x
J. Valved outlets or fixtures with hose attachments that may constitute a cross connection to:								
1. Toxic substances	x			x	x		x	x
2. Nontoxic substances		x		x	x	x	x	x

* For backflow or backsiphonage

Cross Connections, Hazards, and Recommended Types of Prevention Devices

(Source: "Cross Connections & Backflow Prevention". 1974. 2nd Edition. AWWA).

TABLE 2 Continued

Toxic Substance. Any substance (liquid, solid, or gaseous), including raw sewage and lethal substances, that when introduced into the water supply system creates or may create a danger to the health and well being of the consumer.

Hazardous connections: Flush valve toilet, direct connection to contaminated vessel or system, ship watering point.

Nontoxic Substance. Any substance of a nonpoisonous nature that may create a moderate or minor hazard to the domestic water system.

Hazardous connections:

1. Connections to food processing lines, such as those carrying syrups, lard, beer.
2. Connections to steam and steam boilers where the steam does not come in contact with toxic substances.
3. McDaniel tees or steam clean-up connections in food plants, apartment house boilers, or pressing boilers where toxic compounds are not used.
4. Connections to enclosed circulating systems, such as radiant-heating systems and refrigerated-water systems where toxic compounds are not used.

Air Gap. Used to prevent either backflow or backsiphonage, an air-gap separation is the unobstructed vertical distance through the free atmosphere between the lowest opening from any pipe or faucet supplying water to a tank, plumbing fixture, or other device and the flood level rim of the receptacle.

Reduced-Pressure Device (Backflow Preventer). Used as protection for all direct or indirect water connections where the device may be subject to backpressures from toxic chemicals, sewage, or other lethal substances.

Double Check-Valve Assembly (Backflow Preventer). Used as protection for all direct or indirect water connections through which foreign substances might enter the system in such concentrations as to constitute a nuisance or be aesthetically objectionable. Examples are foods, beverages, or other substances that do not constitute a health hazard.

Pressure Vacuum Breaker (Backsiphonage Preventer). Used as protection for direct or indirect water connections to all types of polluted or contaminated liquids where the preventer is not subjected to back-pressures. This device may be installed for use under continuous line pressure.

Atmospheric Vacuum Breaker (Nonpressure-Type Backsiphonage Preventer). Used as protection for direct or indirect water connections to all types of polluted or contaminated liquids where the preventer is not subjected to backpressures and is installed on the discharge side of the last control valve. This preventer should not be subjected to continuous flows for periods of more than 12 hr.

Explanation of Terms

413

SELF-TEST

1. What is an air gap?	A gap between the supply pipe and the flood level rim that is twice the diameter of the supply pipe.
2. A nonpressure vacuum breaker is used to prevent __________.	backsiphonage
3. A double check - double gate valve assembly is used to prevent __________.	backflow
4. Cross connections that occur in pumps, tanks, and lines handling toxic substances could be prevented by either of two devices. Name them.	Air gap Reduced pressure zone device.

SUGGESTED READINGS

If you wish to find further information on the topics discussed in the module, the following books are recommended.

1. Backflow Prevention and Cross Connection Control, 1966. AWWA Manual M14, AWWA, Denver, CO.
2. Cross Connection Control Manual. 1973. Environmental Protection Agency (EPA-430/9-73-002) Washington, D.C.
3. Cross Connections and Backflow Prevention. 1974. 2nd Edition. AWWA, Denver, CO.
4. Manual of Cross Connection Control Recommended Practice. 1969. Foundation for Cross Connection Control Research, University of Southern California, Los Angeles, CA.
5. Van Meter, R.O. 1970. Implementation of an Effective Cross Connection Control Program. Presented at South Carolina Public Health Department Cross Connection School. Columbia, SC.

POST-EVALUATION (10 pts. each question)

1. Who is liable if a neglected cross connection results in the public being exposed to a disease or contamination in the public water supply?
2. What is a cross connection?
3. The appropriate preventive devices for backflow are:
    a. Nonpressure vacuum breaker and double check - double gate valve.
    b. Double check - double gate valve and pressure vaccum breaker.
    c. Double check - double gate valve and reduced pressure zone device.
    d. None of the above.
    e. All of the above.
4. What is the main disadvantage of the air gap method for correcting cross connections?
5. What can the operator do to prevent cross connections in the treatment plant?
6. How would you correct a cross connection in a chemical feed machine handling a non-toxic substance that is subject to back pressure?
7. Describe the hydraulic principle that explains why the reduced pressure zone preventer works.
8. What is the disadvantage of using a double check - double gate valve assembly?
9. Why does a cross connection present a hazzard?
10. What is a toxic substance?

ANSWERS

1. The water purveyor or supplier.
2. A link either permanently or temporarily connecting a source of contamination (unsafe) and a potable water (safe) supply system.
3. c
4. Easy to bypass.
5. Conduct frequent surveys checking all possible areas for cross connection.
6. Install a reduced pressure device or double check - double gate valve.
7. Water will not flow from a zone of lower pressure to a zone of higher pressure.
8. You cannot tell easily when it malfunctions.
9. It can expose the public to diseases or toxic substances through contaminated water.
10. Any substance, including raw sewage and lethal substances, that when introduced into the public water supply creates or may create a danger to the health and well being of the consumer.

MODULE 13

SELF-INSTRUCTIONAL

James H. Shaddy - NMSU

DISTRIBUTION SYSTEM

PREREQUISITES: Module One - Basic Mathematics; Module Two - Basic Chemistry
Module Three - Analysis Procedure; Module Four - Microbiology
Module Five - Basic Electricity; Module Six - Hydraulics
Module Seven - Chlorination; Module Eight - Plant Operations
Module Nine - Surface Water; Module Ten - Ground Water
Module Eleven - Pumps; Module Twelve - Cross Connections
Module Fourteen - Safety

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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DO NOT FILM THIS

SELF-EVALUATION

1. True or False (1 point each)
   a. The most common water service meter in use today is the displacement type meter.
   b. A displacement type meter is not accurate at low flows.
   c. When a meter shows significant wear it will tend to under - register.
   d. Fire service meters are usually compound meters.
   e. Large meters are more accurate on small flows than small meters.
   f. It is not necessary to test a meter before placing it into service.
   g. The ability to exist for a long time without deterioration is an important factor when selecting pipe.
   h. Asbestos - cement pipe is nonconductive.
   i. Steel pipe is not prone to corrosion and therefore does not need to be coated or lined.
   j. The type and size of a meter should be based on the customer demand and safety requirements.

2. The carrying capacity of water mains can be reduced by: (10 pts.)
   a. tuberculation
   b. vacuum breakers
   c. lining
   d. looping

3. How often should water service meters (5/8 inch) be inspected and tested? (10 pts.)

4. __________ meters are used where the water demand varies considerably. (10 pts.)
   a. pilot tube
   b. orifice
   c. compound
   d. venturi

5. What are the consequences of having a poorly metered water system? (10 pts.)

6. _________ valves are generally used to sectionalize (isolate a section) a water system. (10 pts.)
   a. globe
   b. diaphragm
   c. butterfly
   d. gate

7. Name the five main types of pipe used in water distribution systems. (10 pts.)

8. If a valve is closed too quickly, it will cause the water to come to a sudden stop causing waves of pressure that oscillate back and forth in a section of pipe. This reaction is called: (10 pts.)
   a. static pressure
   b. static lift
   c. water hammer
   d. oscillating plume

9. The term that reflects the roughness or smoothness of the interior of a pipe is known as: (10 pts.)
   a. H-Factor
   b. Tuberculation
   c. C-Factor
   d. Cavitation

10. What causes a displacement meter to over register? (10 pts.)

ANSWERS

1. a. T
   b. F
   c. T
   d. T
   e. F
   f. F
   g. T
   h. T
   i. F
   j. T

2. a

3. every 10 years

4. c

5. Loss of revenue
   Wasted water that can lead to a shortage
   System has low value when trying to sell bonds
   Poor record of water use
   Cannot account for lost water due to leaks

6. d

7. Cast-iron
   Asbestos-cement
   Plastic
   Steel
   Concrete

8. c

9. c

10. Sediment on the disc, piston or chamber.

INTRODUCTION

The distribution system begins at the discharge of the high service pumps and ends at the customers side of the meter. This includes water mains, service lines, valves, fire hydrants, storage tanks, booster stations, pressure regulators, and meters. This module has been limited to presenting basic information on meters, pipe, valves and disinfection procedures. Some of the information contained in this module has been reprinted with permission from the "Water Distribution Operator Training Handbook," copyright 1976, American Water Works Association, Denver, Colorado.

PERFORMANCE OBJECTIVES

When this module is completed you will be able to show that you have mastered the following concepts:

1. Types of meters
2. Selection of meters
3. Installation of meters
4. Testing meters
5. Maintenance and repair of meters
6. Types of pipe
7. Various uses of pipe
8. Types of valves
9. Various uses of valves
10. Disinfection provedures

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

WATER METERS

Meters serve a variety of purposes in the waterworks industry. Several uses are listed below:

1. Set cost according to the amount of water used. This is the most common use.
2. Determine water flow in main line into different areas allowing for system control.
3. Measure flow in and out of reservoirs.
4. Measure influent to and effluent from treatment plants.
5. Allow accurate blending of waters of different quality.
6. Specific chemical dosages can be introduced when the water is metered.
7. Determine operation efficiency of water utility i.e. if some water is unaccounted for, a survey can be initiated to locate the loss.
8. Provide a record of water use.
9. Allows customer to only pay for the water used.

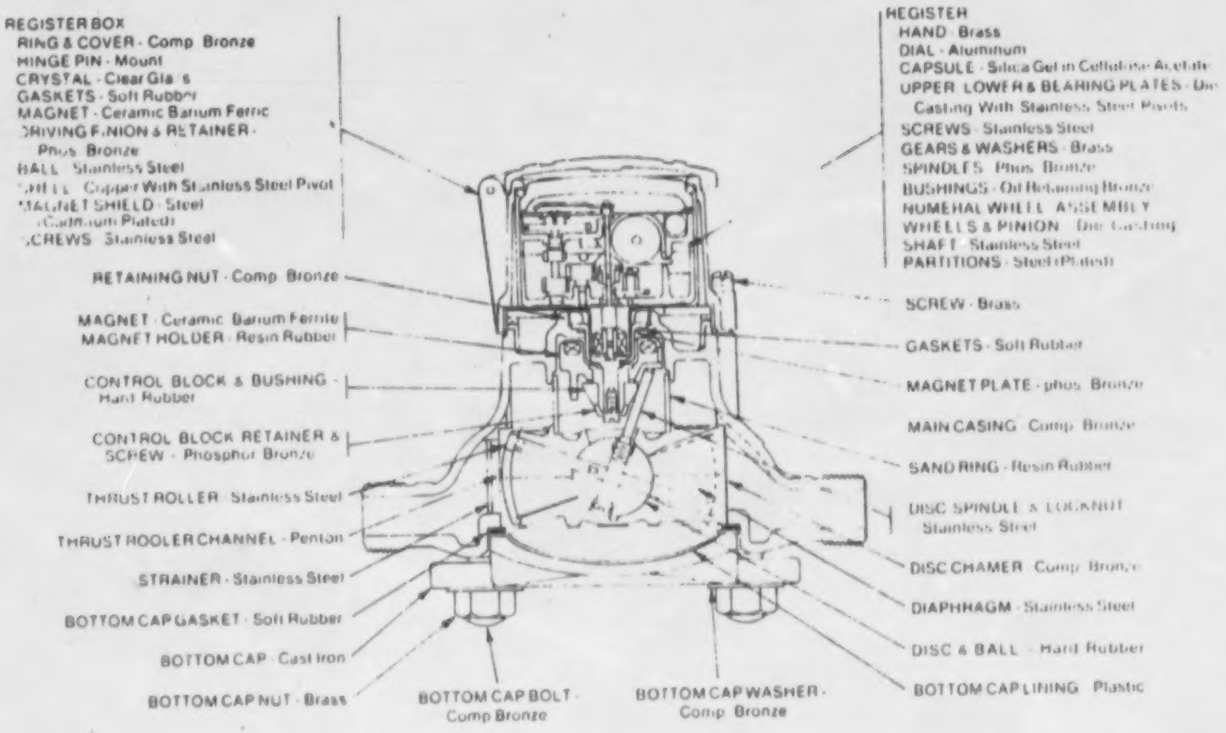
TYPES OF WATER METERS

There are five general classifications of water meters: positive displacement meter, current meters, proportional meters, compound meters and fire service meters.

The water service meter is the most common in use and is usually a displacement type meter. This meter contains a measuring chamber of a given volume with a fitted disc or piston. The disc or piston goes through a simple cycle of motion that corresponds to a single filling and emptying of the chamber. These cycles are transferred to the meter register either in gallons or cubic feet to illustrate how much water has passed through the meter. The nutating-disc meter (Figure 1) and the oscillating-piston meter are the most common in use today. The major advantage of the displacement meters is that they are quite accurate at low flows and are generally not affected by the character of the water. The major disadvantage is that they have a higher than normal head loss. Most of the meters in use today are magnetically driven. They will over register only to a limited extent if small amounts of sediment accumulate on the disc, piston, or chamber. Significant deposits of sediment, however, can cause the meter to stop registering. These meters will also under register when worn. In addition, under registration and excessive wear can come about by operating a displacement meter in excess of its stated capacity. Normally 5/8" to 3" meters are used, however, the disc type is produced in sizes up to 6". But as the size becomes larger, the sensitivity at low rates of flow decreases.

The proportional meter (Figure 2) derives its name from the fact that only a portion of the water is measured by diverting it into a loop that contains a measuring device. The remainder of the water passes through without encountering a measuring device. Usually a displacement or current meter is used in the loop to measure the diverted flow. The meter is then calibrated to register the full amount of water in the main pipeline. The advantage of this meter is that it can measure large volumes of water with low loss of head. It is not accurate at low flows however.

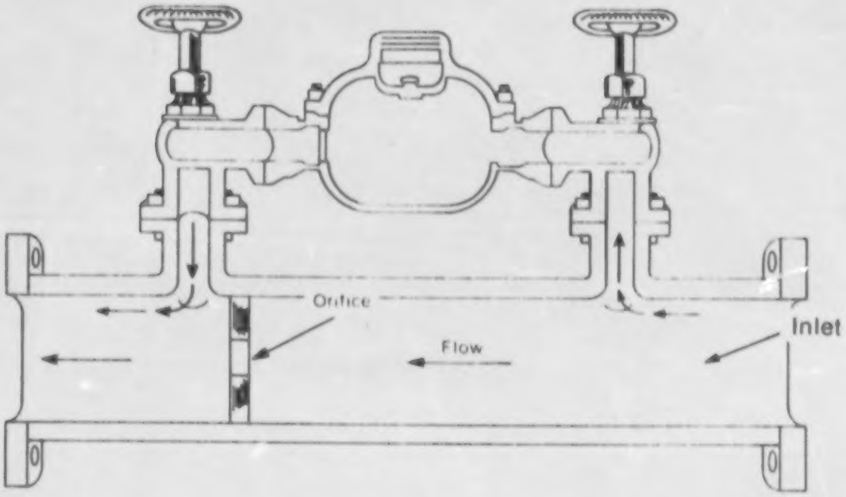
FIGURE 1


REGISTER BOX
RING & COVER - Comp Bronze
HINGE PIN - Mount
CRYSTAL - Clear Glass
GASKETS - Soft Rubber
MAGNET - Ceramic Barium Ferric
DRIVING PINION & RETAINER - Phos Bronze
BALL - Stainless Steel
WHEEL - Copper With Stainless Steel Pivot
MAGNET SHIELD - Steel (Cadmium Plated)
SCREWS - Stainless Steel
RETAINING NUT - Comp Bronze
MAGNET - Ceramic Barium Ferrite
MAGNET HOLDER - Resin Rubber
CONTROL BLOCK & BUSHING - Hard Rubber
CONTROL BLOCK RETAINER & SCREW - Phosphor Bronze
THRUST ROLLER - Stainless Steel
THRUST ROOLER CHANNEL - Penton
STRAINER - Stainless Steel
BOTTOM CAP GASKET - Soft Rubber
BOTTOM CAP - Cast Iron
BOTTOM CAP NUT - Brass
BOTTOM CAP BOLT - Comp Bronze
BOTTOM CAP WASHER - Comp Bronze
REGISTER
HAND - Brass
DIAL - Aluminum
CAPSULE - Silica Gel in Cellulose Acetate
UPPER LOWER & BEARING PLATES - Die Casting With Stainless Steel Pivots
SCREWS - Stainless Steel
GEARS & WASHERS - Brass
SPINDLES - Phos Bronze
BUSHINGS - Oil Retaining Bronze
NUMERAL WHEEL ASSEMBLY
WHEELS & PINION - Die Casting
SHAFT - Stainless Steel
PARTITIONS - Steel (Plated)
SCREW - Brass
GASKETS - Soft Rubber
MAGNET PLATE - phos Bronze
MAIN CASING - Comp Bronze
SAND RING - Resin Rubber
DISC SPINDLE & LOCKNUT Stainless Steel
DISC CHAMER - Comp Bronze
DIAPHRAGM - Stainless Steel
DISC & BALL - Hard Rubber
BOTTOM CAP LINING - Plastic

Nutating-Disc Displacement Type Meter

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

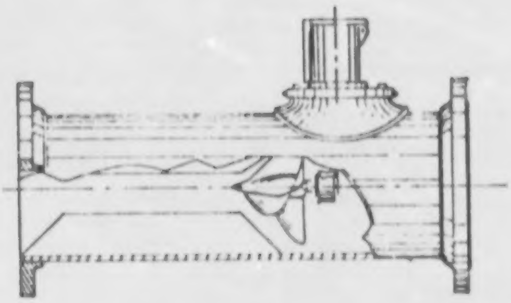
FIGURE 2



Proportional Meter

(Source: "Water Distribution Operator Training Handbook." 1976 Awwa.)

FIGURE 3



Propeller Meter

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

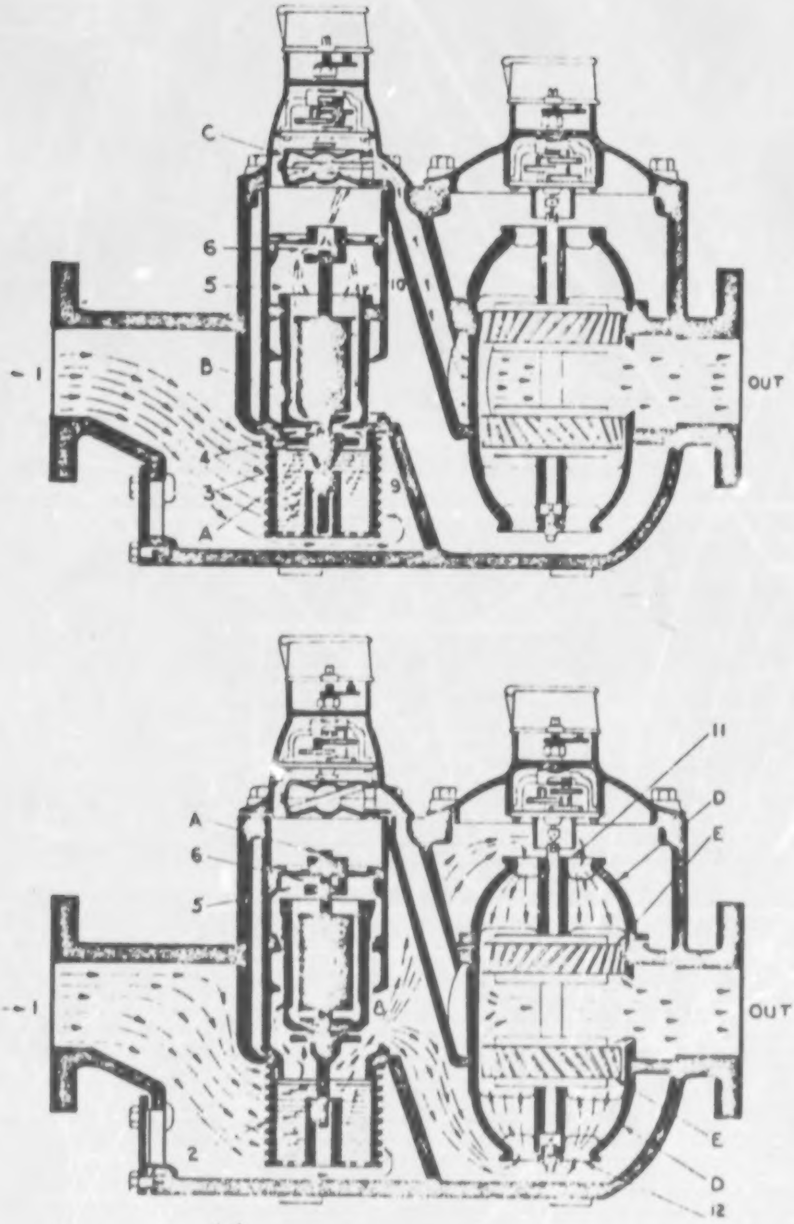
The current or velocity meters consist of two types: turbine and propeller (Figure 3). In both meters the measuring device is a bladed wheel that rotates as the incoming water strikes it. The number of rotations registers the amount of water passing through the meter. The major disadvantage of the current meter is that it is not accurate at low flows. This is because the water must be moving at a sufficient velocity before the wheel will rotate. They do have a relatively low loss of head. These meters do tend to over-register when the blades of the wheel become partially clogged or coated with sediment or other material. These meters are most frequently used to measure sustained high flows.

The compound meters (Figure 4) are used where the water demand varies widely. These meters are usually a combination of two different types of meters (i.e. displacement and turbine) housed in the same case and combine the merits and characteristics of both into the compound meter. A suitable automatic valve system is incorporated which allows, for example, the displacement meter to operate at low flows and the turbine meter to operate at high flows. In some cases instead of using a single large meter, a series of small meters in a battery (Figure 5) or manifold have been installed. This arrangement may be employed to permit a utility to use displacement meters, since they are quite accurate, to permit expansion of the system in the future and allow repair or removal of a meter without closing down the entire system.

The fire service meters are usually used to meter services that provide water for fire fighting purposes. They are compound type meters but differ in that the main line side is metered using a proportional meter during high flow or demand. This permits a high rate of flow at a very low loss of head. During low flows the displacement meter is used because of its accuracy under these conditions.

Other types of meters that may be encountered are venturi (Figure 6), oriface (Figure 7), pitot tube (Figure 8) and rotometers. However these are seldom used for customer service.

FIGURE 4

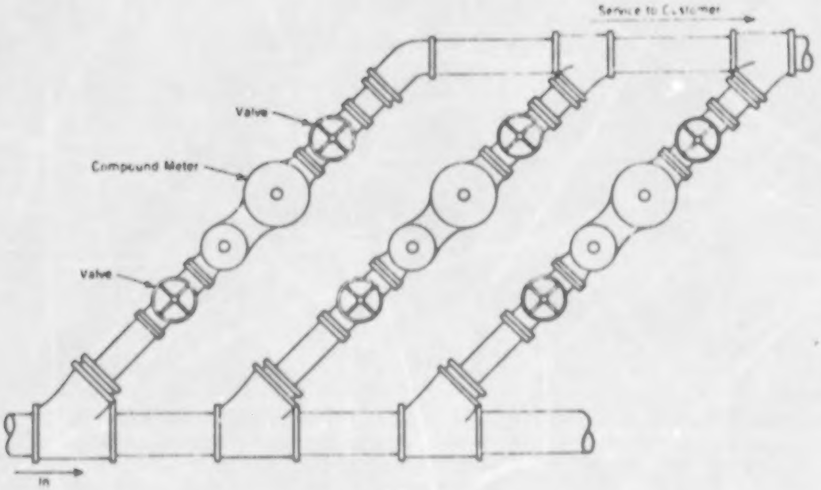

C
6
5
10
1
B
OUT
4
3
9
A
11
D
E
A
6
5
1
OUT
2
E
D
12

Compound Meter

Top-Low Flow; Bottom-High Flow

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

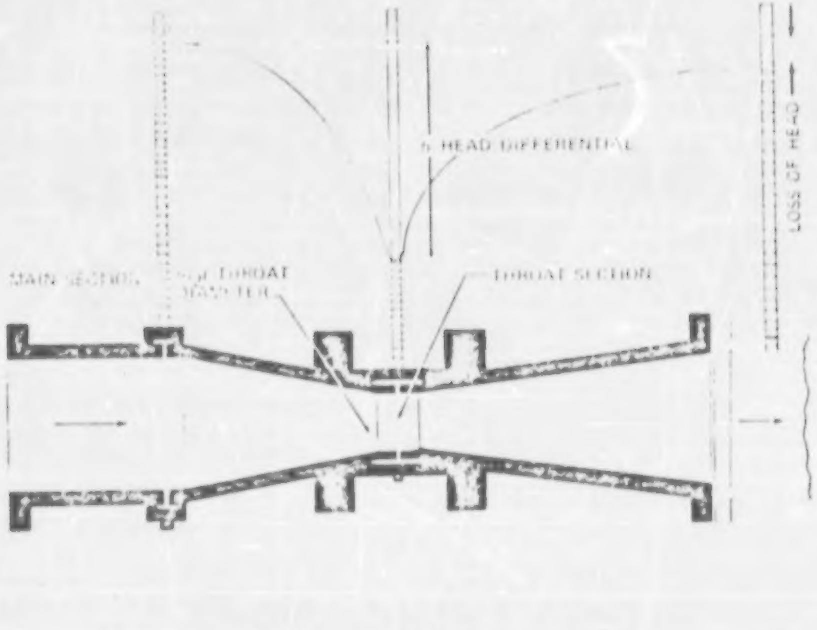
FIGURE 5


Service to Customer
Valve
Compound Meter
Valve
In

Meter Battery

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

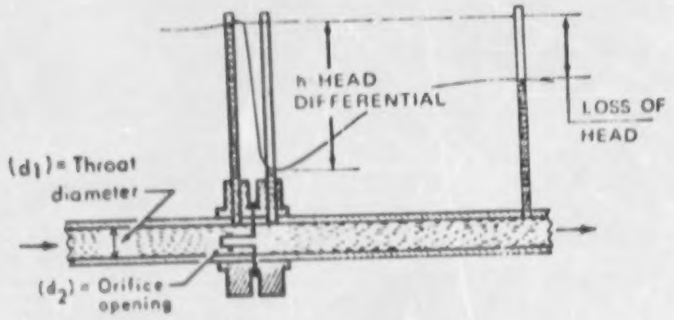
FIGURE 6


h HEAD DIFFERENTIAL
LOSS OF HEAD
MAIN SECTION
THROAT DIAMETER
THROAT SECTION

Venturi Meter

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

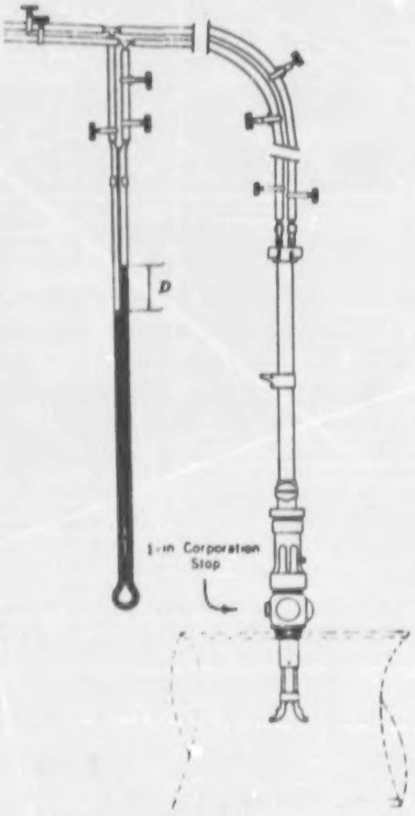
FIGURE 7


h HEAD
DIFFERENTIAL
LOSS OF
HEAD
(d_1) = Throat
diameter
(d_2) = Orifice
opening

Orifice Type Meter

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

FIGURE 8


D
1-in Corporation
Stop

Pitot Tube Meter

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

SELF-TEST

1. List at least six reasons to meter a water system.	a. set cost according to use b. have better control over system c. measure flow in and out of reservoirs d. measure influent and effluent from treatment plant e. allow accurate blending of waters of different quality f. allow introduction of specific chemical dosages g. determine efficiency h. provides record of water use i. allow customer to pay only for what he uses
2. Describe how a displacement meter operates.	The meter has a chamber with a specified volume. In the chamber is either a disc or piston. When the disc or piston goes through a single cycle of motion that corresponds to a single filling and emptying of the chamber, the amount of water that has passed through is registered on the meter register in either gallons or cubic feet.

3.	List the main advantage and disadvantage of the nutating-disc and oscillating-piston meters.	Advantage: very accurate at low flows Disadvantage: they have a higher than normal head loss
4.	What is the main advantage of the proportional meter?	It can measure large volumes of water with low head loss.
5.	When should you use current or velocity meters?	When you have large, sustained flows.
6.	When should you use compound meters?	In situations where the water demand varies greatly.
7.	Describe a compound meter.	The compound meter usually consists of two types of meters. One is used to measure high flows and the other measures low flows.
8.	Name the five most frequently encountered service meters.	a. Positive displacement b. current c. proportional d. compound e. fire service

SELECTING THE TYPE AND SIZE METER TO USE

The type of meter to use is determined by the range of flow rates or customer demand, plus allowable pressure loss and possible safety requirements i.e. fire service regulations.

Frequently the size of the meter is chosen merely to match the size of the pipe, but the pipe is often installed oversize to allow for possible future increases in water use or to reduce pressure loss in a long length of pipe. It is not uncommon for services to be over metered where preliminary sizing studies have not been made. Thus, if you have a 3 inch pipe, before putting on a 3 inch meter, check to see if the water demand really requires that size of meter.

For small flows (less than 1 inch meters) found primarily in residential areas, the displacement type meter is most commonly used. Most residential services are metered with the 5/8 inch size meter having 3/4 inch connections. Note that normal flows should not be more than approximately one-third of the maximum capacity if long life is the objective.

For medium flows (1-4 inch meters) that allow 1 1/2 inch meters, the displacement type is commonly used. Where 2-4 inch meters are required, displacement, turbine and compound meters are used. The displacement type is simpler, lower in cost and registers reasonably well at slow flow rates. However, the compound type gives better accuracy on very slow flows or leaks and lower pressure loss at high flow rates. Usually the choice depends on what average flow rates are to be measured. If the meter is used between 5% and 35% maximum rated capacity, and accuracy at very slow flows is not important, use the displacement type. If accuracy at low flows is desired, but large capacity is also needed, use the compound type. If large capacity is needed and flows are usually above 10-15% of maximum rating and slow flow accuracy is secondary, use the turbine type. In certain cases, for 3 inch or larger lines, occasionally two or three meters are manifolded or installed as a battery. For 3 inch lines, two, 2 inch meters are used; for 4 inch lines, use three, 2 inch meters. These meters are usually displacement meters. For 6-10 inch lines, the battery should consist of compound meters.

In large flow situation, the choice lies between the compounds, turbine, propeller or fire service types. Generally the compound meter is used for general commercial or industrial services. Turbine meters are used where flows are large, minimum flow usually above 10-15% of maximum rating. Turbines produce little pressure loss. Propellers are used primarily for main line or pump station discharge measurement. Where requirements for safety dictate, the fire service meters should be used. They allow large flow with little pressure loss.

There are no hard and fast rules for selecting the correct size of meter for a particular service. Specific factors that should be considered are listed below:

1. Pressure and quality of water available in the main at service connections.
2. Differences in elevation between street and highest water fixtures.
3. Friction losses in service line.
4. Meter friction loss.
5. Friction losses in house plumbing.
6. Rate at which water is to be used (customers demand)

For specific steps in estimating the customers peak demand and sizing the customers service and meter read chapters 4 and 5 of "Sizing Water Service Lines and Meters" AWWA Manual M22.

SELF-TEST

1. Name three factors that should be considered in determining the type of meter to use.	a. customer demand b. allowable pressure loss c. safety requirements
2. What type of meter is generally used for small flow situations? Why?	Displacement type Its accurate at low flows.
3. For medium flows where the flow may vary considerably and you desire accuracy, which meter should you use?	compound meter
4. Where are propeller meters generally used?	Water mains and pump station discharge.
5. List at least five factors that should be considered when determining the size of a meter.	a. pressure and quality b. elevation of highest water fixture c. friction losses in service line d. meter friction loss e. friction loss in house plumbing f. customer demand

INSTALLING METERS

Customer service meters are located either indoors or outdoors. There are advantages and disadvantages either way.

Indoors:

Advantages

1. Potentially lower installation costs
2. Reduced damage and maintenance through elimination of exposure to extreme weather conditions
3. Opportunity for customer contact via the meter reader

Disadvantages

1. Missed readings due to being unable to enter residence
2. Possibility of hot water damage
3. Basement flooding

Outdoors:

Advantages

1. Meter located at point of delivery to customer
2. Elimination of a separate curb box
3. Reduction in meter damage from water heater failure
4. No requirement to enter customers home

Disadvantages

1. High cost due to frost protection
2. Reading difficulty
3. Frequent maintenance due to flooding, snow, vandalism, etc.

However, with the advent of inexpensive and reliable remote-meter-reading devices most of the disadvantages of indoor settings have been eliminated. For example, the meter set inside the house can now be read from the outside eliminating the need to enter the house to make the reading.

Thus the choice between inside or outside settings of meters can now be made on the basis of overall economics considering initial investment, installation cost, reading cost, and maintenance expense. In addition the elimination of pit hazards, public injury liability and pit maintenance may also figure into the decision to use indoor versus outdoor meters.

The basic requirements of an acceptable meter installation are as follows:

1. Meter is watertight,
2. Upstream shut off valve of high quality provided.

3. Low pressure loss.
4. Meter placed in a horizontal plane for optimum operation.
5. Meter should be easily accessible for service and inspection.
6. Provide for easy reading either directly or via remote reading device.
7. Should be reasonably well protected from frost, mechanical damage, and tampering.
8. It should not be an obstacle or hazard to the customer or interfere with public safety.
9. If the meter is located where water on the floor is undesirable, the installation should include a valve downstream of the meter to prevent drainage during meter service or change out.

When handling meters it is important that all open connections be capped to avoid damage. In addition, meters should be protected from heat and direct sunlight during storage and transit prior to installation or after removal.

Electrical continuity must be maintained through the water line on all indoor settings. Accidental electrocution of service men changing meters is prevented by having electrical bonding around the meter. If the meter setting does not provide a continuous electrical circuit when the meter is removed, a permanent bonded electrical grounding strap should be provided. The National Electrical Code of the Board of Fire Underwriters requires electrical grounding of meters. Most commercially available prepared meter settings provide a continuous metallic circuit (ground), even when the meter is removed from the line.

SELF-TEST

1. What are the advantages of locating the meter inside the customers home?	a. lower installation cost b. reduced damage and maintenance c. opportunity for customer contact
2. What are the advantages of locating the meter outside the customers home?	a. meter is located at point of delivery b. elimination of separate curb box c. reduction in meter damage from water heater damage
3. What impact has the remote meter reading devices had on the location of the meter?	More feasible to locate the meter inside the customers home.
4. Why must electrical continuity be maintained on all indoor settings?	To prevent electrocution of servicemen changing meters.

TESTING METERS

Water meters are subject to wear, deterioration and deposition that may cause the meter to over register or under register. How long the water meter retains its overall accuracy depends on many factors, such as the quality of the water being measured, rates of flow and total quantity, and chemical buildup and abrasive materials carried by the water. All new meters should be tested for accuracy before they are placed in service.

From the customers viewpoint, meters should be tested to protect him against meter inaccuracy that could result in overcharges. However, testing of meters will detect under registeration as well, thus preventing significant revenue loss to the utility.

Since 1968, Missouri has required the following testing frequencies of various sized meters.

Interval Between Tests - Years

Meter Size - Inch

5/8	3/4	1	1 1/2	2	3	4	6 or larger
10	8	6	4	4	4	4	4

Registration Between Tests - 1000 cu.ft.

Meter Size - Inch

5/8	3/4	1
200	300	400

The following description covers the actual steps in testing meters and is reprinted with permission of the American Water Works Association from "Water Distribution Operator Training Handbook" American Water Works Association, Denver, Colorado, copyright 1976.

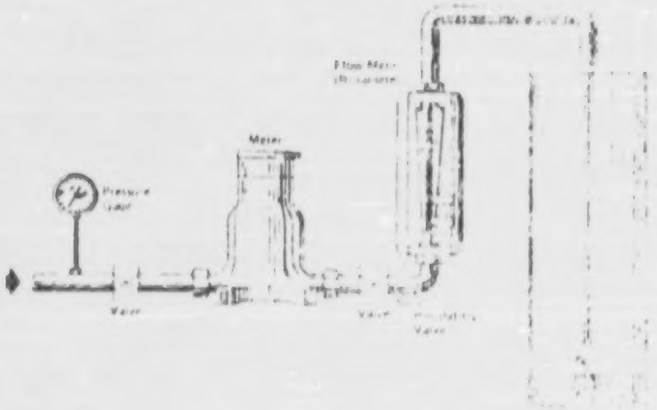
Although the following description covers the actual steps in testing a single 5/8 in. meter, the only differences for testing larger meters are the rates of flow and test quantities used. Test equipment is essentially that shown in Figure 9.

Except for meters being checked upon removal from service, one should follow instructions 1-12. Testing instructions for meters removed from service are included following these itemized instructions.

1. Clamp the meter securely in the test bench, tightening only enough to make a watertight connection; there is a possibility of distorting the meter housing or extruding the washer into the water way if it is tightened too much.

2. Remove the register box cover.

FIGURE 9



Meter Testing Installation

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

3. Open the discharge valve first; then open the inlet valve gradually and run water to waste until the entrapped air is cleared. This process also ensures a full discharge line to the tank.

4. Shut off the discharge valve.

5. Check 100 gal. or 10 cu. ft. tank discharge to ensure that the tank is empty and then close the tank drain valve. Tank discharge should be to an open drain so that any possible leakage of the tank drain valve can also be observed.

6. Set the test hand at the zero mark by revolving the register backward beyond the zero mark and then reversing direction to bring the test dial hand forward to the mark to take up any possible backlash in the gearing (sealed registers on some magnetic-drive meters require a special test ring that sits on top of the register box and can be rotated so that the test hand starts at zero on the test dial).

7. Open the test bench discharge valve as rapidly as prudently possible to the desired rate for the maximum-flow test (15 gpm) and continue the flow at this rate until the meter test hand has made ten complete revolutions; then stop the test at the starting mark. Compare meter accuracy against the scale of the calibrated tank or, if the tank is not calibrated, weigh the water in the tank.

8. Post the results of this test on the record form used.

9. Refer to the change-gear chart and replace change gears with a set that should cause the meter to register within required limits if the meter being tested is a repaired meter and its accuracy does not fall within prescribed limits; repeat the test as outlines (always be sure that the meter tests correctly by rerunning the test after any change in gears is made).

10. If a repaired meter is being tested and is found to register within limits on the maximum-flow test rate, repeat steps 3-8, for the intermediate (2 gpm) and minimum (1/4 gpm) tests, discharging the test water into the 10 gal or 1 cu. ft. tank; the test quantity for these rates is only 10 gal. or 1 cu. ft. and the meter register test hand completes only one full revolution.

11. Remove meter from the test bench after the inlet valve of the test bench has been closed and pressure has been released by a partial opening of the discharge valve.

12. Drain meter, seal register, and place dust caps on the meter spuds before the meters are put in storage.

To determine the condition of a meter upon removal from service arrange the order of test flows according to minimum intermediate and, finally, the maximum flow test. If a meter has been in service for some time and is first tested at the high rate of flow, there is a possibility of freeing the disc and thereby obtaining a false impression of the meter's condition at lower rates. A meter should be tested as soon as possible after removal from service to prevent drying out of deposits in the measuring chamber since this dried condition tends to give an adverse impression of the meter's condition while it was in service.

Particular attention is called to the fact that the calibration of a tank is based on its rated capacity, and if lesser quantities are used in testing, as is sometimes done, the calibrated percentage errors are not valid. For example, a 10 gal. tank may be used as a 1 gal. tank by lowering the water level to the 9 gal. mark and running water to the 10 gal. mark. This procedure is not recommended but is sometimes carried out to save testing time. Under such conditions, each 1 per cent error on the calibration strip becomes 10 per cent.

The rate of flow indicator (rotometer) can be used as a substitute or adjunct for the calibrated tank. However, it should be noted that a rate-of-flow indicator is affected by water temperature below the 1 gpm rate. Most rate-of-flow indicators are calibrated for 70F, and viscosity changes due to temperature affect the reading.

Rate-of-flow indicators usually are equipped with a pointer and indicate true rates at the minimum flow points. Rates are raised for low-temperature water and lowered for high-temperature water. To calibrate or to use the rate-of-flow indicator, the following formula is used.

$RT=V$
where R = rate of flow in gallons per minute
T = time of flow in minutes
V = volume of test tank in gallons
Example: it takes 15 minutes to fill a 10 cu. ft. (75 gal.) test tank:

$R = V/T = 75/15 = 5$ gpm

This check on accuracy of low flow calibration is required only when a marked change in temperature of the test water occurs, probably not more often than four times a year.

Multiple testing of meters is identical to the testing of one meter except for one important factor. In multiple meter testing, it is not possible to use the meter test dials to fix upon the test quantity since each meter has a slightly different accuracy. The test quantity is discharged into the tank through several meters in series and the flow is stopped when the scale on the tank indicated the exact quantity has been delivered. Each meter's accuracy is determined from the reading of that meter's register. It is very important that the arithmetic of the test be clearly understood when meters are tested in this manner. In the tests described for testing one 5/8 in. meter, only two quantities were used: 100 gal. or 10 cu. ft. for the maximum flow test, and 10 gal. or 1 cu. ft. for the intermediate and minimum flow test. One full revolution of the test hand of a 5/8 in. meter registers either 10 gal. or 1 cu. ft. and the test hand circle is divided into ten equal parts. Therefore, on the maximum-flow test, when the test hand makes ten full revolutions, each subdivision of the test dial circle represents a 1 per cent variation. On the intermediate and minimum-flow tests of 10 gal. or 1 cu. ft., the test hand makes only one revolution, and each subdivision represents a 10 per cent variation.

When 5/8 in. meters are tested in groups and the exact test quantity is discharged into the tank, the percentage error between divisions of the test dial depends on the quantity, being 1 per cent for 100 gal.(or for 10 cu. ft.) and 10 per cent for 10 gal. (or 1 cu. ft.). Furthermore, whether the meter is fast or slow must be determined. If, in group testing 5/8 in. meters on a quantity of 100 gal, the test hand of one meter indicates ten full revolutions plus one additional mark (1 gal.), the meter has registerd 101 gal. when only 100 gal. were delivered, so the meter is registering 101 per cent of true quantity, or 1 per cent fast. Similarly, if the test hand of another meter has made ten revolutions minus two marks (2 gal), it has registered only 98 gal. when 100 gal. have been delivered. It therefore is registering 98 per cent of true quantity, or 2 per cent slow.

When 10 gal. (or 1 cu. ft.) are used in multiple testing, each division of the test dial circle represents a 10 per cent error, and if a meter register shows on the test that the test hand has only moved 9/10 of the full circle, it is registering only 90 per cent. Unless meter registers with center sweep test hands or special test registers are used, it is necessary to interpolate between marks for more accurate readings.

Although anxiety is often expressed over the time involved in testing meters at low rates of flow and large test quantities, testing meters in multiple can reduce this concern. Furthermore, a relatively low cost, automatic electrical cutoff valve or warning alarm can be installed in the test bench unit, which makes it unnecessary to stand by to ensure against overrun of the test.

Field testing is usually confined to meters larger than 2 in. in size and is recommended for all sizes of current and compound types. Very few meter shops have tank facilities for the quantities of water needed to test these large meters. Furthermore, the accuracy of some current and compound meters may be affected by the configuration of pipe fittings directly ahead of the meters.

Field testing of meters is essentially the same as shop testing, except that, instead of using a tank to measure the test water, a comparison is made between the meter to be tested and one that has been previously calibrated. The two meters are connected in series and the test water is discharged to waste. Since the calibrated meter is not 100 per cent accurate at all flows, it is necessary to use a special calibration curve to adjust for different rates of flow in order to compute the accuracy of the meter under test.

One very important point to remember in field testing is that both meters must be full of water and under positive pressure. The control valve for regulating flow, therefore, should always be on the discharge side of the calibrated meter. A control valve on the inlet side of the meter configuration or one located between the two meters should not be used.

The discharge of test water often presents a problem in field testing meters. An additional problem is the selection of a test meter with sufficient capacity to deliver the high rates of flow required for the maximum flow test rate. It is often necessary to use a rate lower than those for the maximum flow test of the large meters, and, in many instances, a maximum rate of 500 gpm or less is used. This rate, however, is usually sufficient to indicate a large meter's accuracy at the high range of flows. Rates lower than 500 gpm should be used only as an expedient and the established test rates should be employed wherever possible. It is safe to assume that the test curve will flatten out after reaching a peak registration that is approximately 10 per cent of rated capacity and then stay within required limits of registration.

MAINTENANCE AND REPAIR

The maintenance and repair of positive displacement meters require dismantling and thorough cleaning and inspection of all parts, after dismantling, the measuring chamber should be carefully inspected for pitting. Likewise the moving parts and appurtenances i.e. disc, thrust rollers, and slots, should be checked for excessive wear and corrosion. The gear train should run freely and mesh smoothly. Gear teeth should be examined for wear. A meter removed from the field and not worked on for some time should be stored full of water in order to keep deposits soft and make dismantling and cleaning easier.

The following points are important to remember in meter maintenance. Although these principles apply for displacement meters, the maintenance and repair of other types of meters are made according to the same procedures.

1. Clean all meter parts thoroughly.
2. Make sure the gear train runs freely.
3. Check the action of the disc in the chamber before and after assembly in the main casing.
4. Friction is just as detrimental to correct registration as slippage.
5. Store meters away from heat.
6. Use a new meter as a standard of comparison for tolerances and clearances.
7. Retest the meter for accuracy after repair.
8. If necessary, call the manufacturer for advice and help.

SELF-TEST

1. Why should you test meters?	To determine over-registration or under-registration
2. A 5/8 inch meter should be tested after having metered 200,000 cu. ft. of water. True or False.	True
3. All meters less than 2 inches in size should be tested in the shop. True or False.	True
4. How should you store a meter for an extended period before cleaning it.	Full of water.

PIPE

There are many different types of pipe being used today to distribute water. Some of the most common types are cast iron, asbestos-cement, plastic, steel, concrete, copper, brass, and wrought iron.

Following are several pipe performance characteristics that should be considered when selecting pipe.

1. Strength - the ability to with stand a variety of forces.
    a. External forces (crushing strength) i.e. weight of passing traffic if pipe is placed under street.
    b. Internal forces (bursting strength) i.e. delivery pressure, surges, and water hammer. (Normally pipe is chosen by pressure rating. Therefore, care should be exercised when replacing a section of pipe to insure the new pipe has a pressure rating equal to or greater than that of the damaged pipe).
    c. Shear and beam breakage - shear break occurs when the earth shifts. Beam breakage occurs when a pipe is supported unevenly along its length.
2. Durability - the ability to exist for a long time without deterioration.
    a. Inner surface - should not react with the water, should resist corrosion, and have satisfactory flow characteristics. The C Factor of a pipe reflects the roughness of the interior of the pipe. The rougher the interior the greater the friction loss.
       It is desirable to minimize friction loss as much as possible. The higher the C factor the smoother the interior surface of the pipe. New pipe currently being used has a C factor in the 100-150 range (See Hydraulics Module)
    b. Exterior surface - should be resistant to corrosion.
3. Installation - several factors should be considered i.e. weight (heavy pipe usually means more expensive installation) jointing, available sizes, and ease of tapping the line (this may be determined by whether service lines are to be attached to the pipe.)

The cast iron pipe used most commonly today is ductile pipe. However up until about 1948 grey cast iron was used for most water lines. Both types are tough, impervious and easily tapped, but ductile iron because of its chemical composition is stronger, less rigid and has structural properties similiar to steel. Cast iron pipe is lined usually with a cement mortor or other linings to prevent tuberculation (the pitting or growth of nodules inside the pipe.) An external coating i.e. bituminous material, is used to reduce corrosion. This type of pipe, if properly coated and lined, will provide a sound, long lined line. The five types of joints normally used with cast iron pipe are bell and spigot, flanged, ball and socket, mechanical, and push on. The push on joint is the most widely used.

Asbestos-cement pipe is made of asbestos fibers, silica sand and cement. The strength of the pipe is provided mostly by the asbestos fibers. There are two types of asbestos-cement pipe. The type is determined by the method used to develop the strength of the cement.

1. water cured - head supplied by water.
2. autoclaved - head supplied by steam.

Asbestos-cement pipe is light weight and easy to install and tap. It is resistant to corrosion. However certain soil and water conditions can cause deterioration. The pipe has a high C factor. This type of pipe is nonconductive and consequently can neither be electrically thawed or located by an electrical pipe locator. But, being nonconductive eliminates electrolysis as a problem. Asbestos-cement pipe is joined by sleeved couplings made of asbestos-cement. The coupling consists of a sleeve that has two interior rubber rings that allow a watertight seal. This joint can be deflected up to 6 degrees without leakage. The coupling requires no caulking and is relatively inexpensive.

There are four commonly used types of plastic pipe: polyvinyl chloride, polyethylene, polybutylene and acrylonitrile, butadiene, styrene. The use of acrylonitrile, butadiene, styrene pipe is decreasing since it lacks the strength of the other pipes. Plastic material may be thermoplastic or thermosetting. The above mentioned types of plastic pipe are thermoplastic meaning they can be softened and shaped more than once by applying heat. Thermosetting materials cannot be softened after the initial formation of the material (fiber glass pipe). All plastic pipes have a smooth interior surface (thus high C factor). Plastic pipe is lightweight, flexible, resistant to corrosion, easy to handle, easy to tap and should provide a long service life. A variety of sizes are produced. Polyethylene pipe is very flexible and is usually available only in small sizes. Polyvinyl chloride pipe may range from 1/2 to 36 inches. Some plastic pipe is available in long lengths resulting in fewer joints. Plastic pipe is used in both distribution and service lines. Fiber glass (layers of fiber glass bound by pastic resin) pipe is lightweight, flexible, with a high burst strength. It is usually made in large sizes. If it is exposed to the sun, it needs to be protected from deteriorating by coating with a sand-type material. Polyethyline and polybutylene pipe are usually joined by one of two different methods: insert fittings or flaring. Insert fittings require inside fittings at the pipe joints to make the connection. Flaring is similar to flaring performed on copper tubing. With polyethylene pipe, heat is usually necessary to make the plastic easily shapable. Polyvinyl chloride pipe may be joined by a bell and spigot or by a solvent weld. An O ring provides the seal in the bell and spigot method. In the solvent method, a solvent is used that causes both pieces of pipe to be cemented together. Care should be taken to prevent damage to the pipe during backfilling. If plastic pipe is to be exposed to sunlight, it should be coated or covered to prevent deterioration.

There are three types of steel pipe available.

1. Fabricated - electrically welded for large pipe (4-144 inches diameter), made from rolled sheets of steel, electrically welded either longitudinally or in a spiral form for strength.
2. Mill type - (the most commonly used steel pipe 1/2-80 inches) either furnace or electrically welded.
3. Seamless - available only in small sizes (2-4 inches).

Steel pipe is strong, lightweight, easy to assemble, handle and transport. But it is prone to corrosion and requires a lining or coating to maintain its service life. The materials used for lining can be bituminous, cement-mortar, or epoxy. The coating materials may be bituminous, cement-mortar, epoxy, galvanizing, mastic or a protective wrap. Large steel pipe is normally fitted with a vacuum relief device to prevent collapse inward from vacuum occurring in the pipe. Steel pipe may be joined in a variety of ways: welding, compression couplings, push on, threaded couplings, and flanged joints. In these couplings, a resilient gasket forms the water tight seal.

There are three common types of concrete pipes based on the method of reinforcement: steel cylinder, prestressed or not prestressed, and non-cylinder not pretensioned. Concrete pipe is available in sizes 12 inches and larger and is used mainly for transmission and distribution. For large sizes, concrete pipe is generally less expensive than any other pipe. Concrete pipe is strong and easily installed. The main disadvantages are that of being hard to tap because of special equipment and quite heavy. A modified bell and spigot joint is normally used to join concrete pipe. This type of joint does allow for some deflection.

Service piping is the pipe used to connect the distribution mains to the individual customer service. The most important factor to consider in selecting service lines is the ability of the pipe to resist internal and external corrosion. Most service lines are copper, polyvinyl chloride, polyethyline, polybutylene, or in some cases, reinforced plastic. Other materials used in service lines are brass, cast iron, wrought iron, steel, and asbestos-cement. In older systems, lead pipe was used. This should be removed and replaced. In most instances, the utilities own and maintain the service pipe from the distribution main to the meter. It is usually the responsibility of the homeowner to maintain the service line from the meter to the house. Generally service lines are 3/4 - 1 1/2 inches and connected to the distribution mains by a shutoff valve called a corporation stop or cock.

It is important that the proper bidding procedure be used for each type of pipe. Special care should be given when backfilling. These precautions can prevent damage to the pipe and prevent unnecessary expenses for repairing the damage.

Before putting a new main into service or after replacing a portion of an existing main, the pipe should be flushed to remove any dirt or foreign material from the system. Flushing should be of sufficient force to thoroughly clean the interior of the pipe.

SELF-TEST

1.	Name the five most common types of pipe in use today.	cast iron asbestos-cement plastic steel concrete
2.	Name the three pipe performance characteristics that should be considered when selecting a pipe.	strength durability installation
3.	It is acceptable practice to replace an old pipe with new pipe that has a lower pressure rating. True or False.	False
4.	The C Factor reflects the roughness or smoothness of the interior of a pipe. True or False.	True
5.	Ductile cast-iron pipe has characteristics similar to steel pipe. True or False.	True
6.	What type of coating is generally used for cast-iron pipe?	bituminous material
7.	List the two types of asbestos-cement pipe.	water cured autoclaved
8.	Why do you not have to worry about electrolysis in asbestos-cement pipe?	it is nonconductive
9.	Define thermoplastic	The material can be softened and shaped more than once by applying heat.
10.	Name the four main types of plastic pipe.	Polyvinyl chloride Polyethylene Polybutylene Acrylonitrile, butadience, styrene
11.	Fiberglass pipe is thermoplastic. True or False.	False
12.	Why can't plastic pipe be exposed to the sun?	It will deteriorate
13.	Name the three types of steel pipe.	Fabricated Mill type Seamless

14.	Steel pipe will deteriorate unless coated and lined. True or False.	True
15.	Name the three types of concrete pipe.	Steel cylinder Prestressed or not prestressed Noncylinder not prestressed
16.	What is the main use for concrete pipe?	Transmission and distribution lines
17.	What is a service pipe?	Pipe running from the main to the customer
18.	Why is flushing necessary?	To remove all dirt and foreign material from the pipe.

VALVES

Valves can be categorized in many different ways i.e. by use, by design, or by the type of material from which the valves are made. The following discussion of valves will be based on their design. The four most common designs of valves are diaphrahm, globe, rotary, and slide (Figure 10).

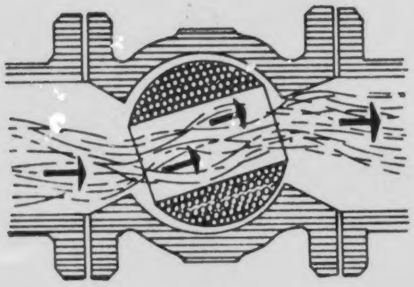
The diaphragm valve contains a flexible piece inside the body of the valve that can be adjusted up or down by a stem. The material for the flexible piece may be rubber, leather, or some other material that is attached to the edge of the valve. When the piece (flexible) is depressed it stops or regulates the flow of water.

In the globe valve, there is a flat or tapered disc of rubber or leather that can be raised or lowered onto a seat. When the disc makes contact with the seat, the flow of water through the valve is stopped. Another globe type valve is the needle design. This valve has a cone-shaped piece protruding into the waterway to restrict or stop the flow. A needle valve can be used to obtain precise adjustment of small flows.

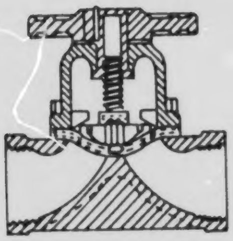
Globe valves can have straight, angle or Y-pattern flows. Some designs are suitable for automatic control.

The ball, butterfly, cone and plug type valves are known as rotary valves. Ball valves have a round ball inside them. The ball has a hole that can be rotated so that water can pass through the valve or be restricted or stopped. The ball is placed between seat washers that prevent leakage. The cone valve is designed with a coneshaped piece within the body of the valve that can be rotated. The cone piece has an opening through it to allow the water to pass. The cone can be turned to restrict or stop the flow through the valve. Plug valves have a cylinder with a hole and operate similiarily to the ball and cone valves. The butterfly valve contains an internal disc that can be turned either to stop or to allow the flow of water. The valve is sealed when the machine edge of the disc contacts the gasket in the valve body.

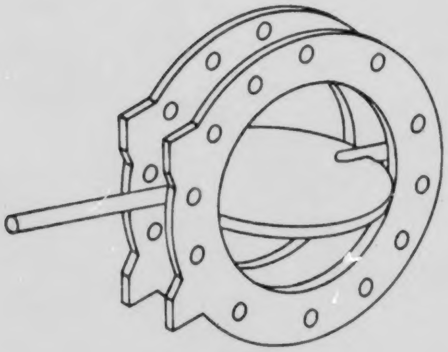
FIGURE 10



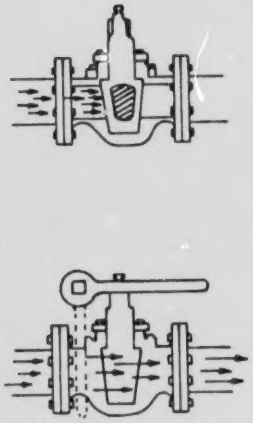
BALL VALVE



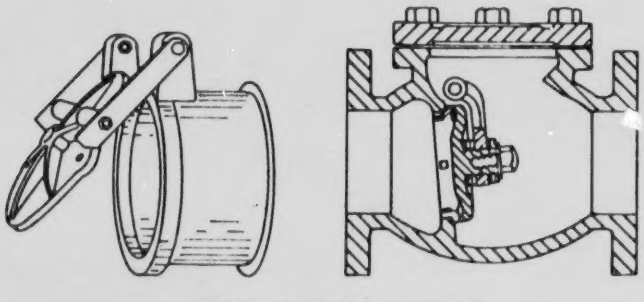
DIAPHRAGM VALVE



BUTTERFLY VALVE



PLUG VALVE

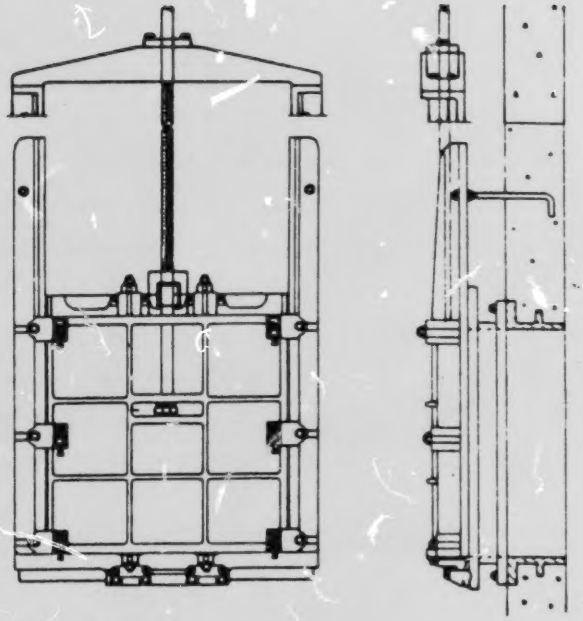


GLOBE (SWING) VALVES

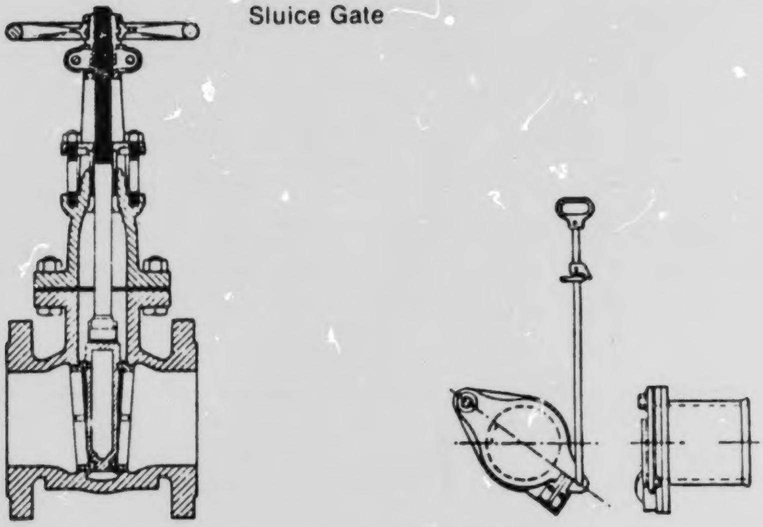
Designs of Common Valves

(Source: "Water Distribution Operator Training Handbook." 1976 AWWA.)

FIGURE 10 (Continued)



Sluice Gate



Gate Valve

Shear Gate Valve

Designs of Common Valves

The most common slide valves are called gate valves, sluice gates, and shear gates. A gate valve contains a disc that either rises from or drops into the flow via a channel that keeps it aligned. The discs in gate valves can be of either a single, double, wedge, nonwedge, or knife type. Since the disc can be raised completely out of the water there would be little loss of flow in the line due to the valve. Sluice gates are generally rectangular in shape and are raised or lowered to control the flow. The pressure of the water behind the gate provides the seal since this valve is generally associated with dams, weirs, and bulkheads. Shear gates have a plate that covers the opening of the valve. The plate is attached by a pin at one side of the seat. This allows the plate to be slid over the opening. When it is closed a wedge forces it against the seat of the valve. A summary of uses, advantages and disadvantages of the different valves is presented in Table 1.

Within the water distribution system, the diaphragm, slide, rotary, and globe valves are generally used to provide starting and stopping functions. The globe, diaphragm, and rotary valves may also be used to control flows. Pressure regulating valves restrict the flow and thus reduce pressure. Here the globe design with a spring-loaded diaphragm that sets the amount of the opening is used. Air and vacuum relief valves can be installed to eliminate or prevent air or a vacuum from accumulating in water lines. Pockets of air may collect at peaks or high spots and can increase flow resistance by 10-15 per cent. These valves are operated by a float that allows the entry (prevents vacuum) or exit (prevents air buildup) of air depending on the water level. Blow off and drain valves are usually located at low spots in water lines. These are on - off type valves and are for draining water from the line for repairs or blowing out sediment that may accumulate at low points in the system. In most water distribution systems, sectionalizing valves (gate valves) are installed at various points to allow isolation of selected areas that need repair work. Contamination of a part of the water system can also be isolated from the rest of the system using sectionalizing valves. When back flow prevention or cross connection control is needed, one of the most common type valves used is the globe (swing) design. For more detail on this subject see the module on Cross Connections.

TABLE I

VALVE TYPE	COMMON SIZE RANGE IN.	PARTICULARLY ADAPTED TO	MAIN ADVANTAGES	MAIN DISADVANTAGES
Gate valve	1/2 - 24	isolation service in pipe grids	low cost in small sizes; low friction loss; fairly good service life; ease of installation.	high cost in large sizes; large valves are quite heavy; poor for throttling should not be used where frequent operation is necessary.
Butterfly valve	3	isolation and automatic control	low cost in larger sizes for normal service pressures; some types have very short lengths, ease of operation.	higher friction loss than gate valve; must use care in selecting valve, particularly for line-break flow conditions may cause problems when relining pipe; often leaks because of seat damage.
Globe valve	1/2 - 24	isolation is small sizes, flow control in large sizes pressure control	simple construction; dependable; can be used for throttling good for pressure control; sediment or material unlikely to prevent complete closing.	high friction loss; very heavy and expensive in large sizes.
Ball and plub valves	3	isolation and throttling	dependable; very low friction loss; slow shut-off characteristic minimizes closing surges; ease of operation.	expensive, very heavy.

The operation of valves can be accomplished either manually or by power. Manual operation is when the operator turns the valve stem directly or by a geared arrangement designed to make the task easier. The operation of valves by power is accomplished using a motor or hydraulic or air piston to turn the stem. There are two problems that can occur during the operation of valves: cavitation and water hammer. An indication of cavitation may be a noisy or vibrating valve. This can occur as a result of a partial vacuum or void on the downstream side of the valve. When these voids fill with low pressure vapors from the water, the pipe in these areas can collapse. This collapse results in a mechanical shock that causes pockets of metal to break away from the valve surface. Eventually this will result in leaks and a faulty valve. Water hammer on the other hand is caused by shutting a valve too fast. If water is stopped too quickly, shock waves are generated. This will cause a large pressure increase throughout the system. These shock waves move quickly and may inflict extensive damage to the water system. Water hammer can be prevented during the operation of valves by closing them slowly. Cavitation and water hammer can also occur in pumps. (See Pumps module).

SELF-TEST

1. Name the four most common designs of valves.	diaphragm globe rotary slide
2. Which of the valves can be used to control flows?	globe diaphragm rotary
3. The globe valve is generally used in regulating pressure. True or False.	True
4. Air pockets can actually stop the flow of water. True or False.	True
5. Water hammer can result if valves are closed too quickly. True or False.	True

DISINFECTION

Before any new main, pipe, valve, meter or pump is put into service it should be disinfected. The chemicals that can be used for this process are liquid chlorine or sodium or calcium hypochlorites. The three most common methods for disinfecting a system are the continuous feed, slug, and tablet methods.

In the continuous feed method, water from the distribution system or other approved source and the type of chlorine selected are fed at a constant rate into the new main at a concentration of at least 50 ppm (mg./l.) available chlorine. A properly adjusted hypochlorite solution injected into the main with a hypochlorinator, or liquid chlorine injected into the main through a solution-feed chlorinator and booster pump, may be used. The chlorine residual should be checked at intervals to ensure that the proper level is maintained. Chlorine application should continue until the entire main is filled. The water should remain in the pipe for a minimum of 24 hrs., during which time all valves and hydrants along the main must be operated to ensure their proper disinfection. Following the 24 hr. period, no less than 25 ppm (mg./l.) chlorine residual should remain in the pipeline.

In the slug method, a continuous flow of water is fed with a constant dose of chlorine (as in the previous method) but with rates proportioned to yield a chlorine concentration of at least 300 ppm (mg./l.). The chlorine is applied continuously for a period of time to provide a column of chlorinated water that will contact all interior surfaces of the main for a period of at least 3 hrs. As the slug passes tees, crosses, and bends, proper valves must be operated to ensure their disinfection. This method is used principally for large diameter mains where continuous feed is impractical.

Because the tablet method precludes preliminary flushing it is considered the least satisfactory, although it is commonly used for small diameter mains. Calcium hypochlorite tablets are placed in each section of pipe, hydrants, and other appurtenances. These tablets should be placed on the top of inner walls of the pipe with approved adhesives. For the most uniform disinfection, the tablets should be placed in the pipe during installation. The main should then slowly be filled with water at a velocity of less than 1 fps to prevent washing of the hypochlorite to the end of the main. The final solution should have a residual of at least 50 ppm (mg./l.) and should remain in contact for a minimum of 24 hrs.

Regardless of the method used, it is necessary to make certain that backflow of the strong chlorine solution into the supply doesn't occur. After the prescribed contact period, the chlorinated water should be flushed to waste until the remaining water has a chlorine residual approximating that throughout the rest of the system. Bacteriological tests as prescribed by the authorities should be taken. If the results fail to meet minimum standards, the disinfecting procedure must be repeated and the results tested again before placing the main in service. One should remember that too much chlorine for an excessive time can damage brass and other fittings.

SELF-TEST

1. What are the three main methods of disinfecting the distribution system?	Continuous Feed Slug Method Tablet Method
2. What are the three chemicals used in disinfection?	Liquid chlorine Sodium hypochlorite Calcium hypochlorite
3. If after disinfecting a system, bacteriological tests are run and fail to meet the standards, what should you do?	Disinfect again

SUGGESTED READINGS

If you wish to find further information on the topics discussed in the module, the following books are recommended.

1. Automation and Instrumentation 1977. AWWA Manual M2, AWWA, Denver, CO.
2. Fire Hydrants - Installation, Operation and Maintenance, 1970. AWWA Manual M17, AWWA, Denver, CO.
3. Installation of Concrete Pipe, 1961. AWWA Manual M9, AWWA, Denver, CO.
4. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY.
5. Manual of Water Utility Operations, 1975. Texas Water Utilities Association, Austin, TX.
6. Sizing Water Service Lines and Meters, 1975. AWWA Manual M22, AWWA, Denver, CO.
7. Steel Pipe Design and Installation, 1964. AWWA Manual M11. AWWA, Denver, CO.
8. Water Distribution Operator Training Handbook, 1976. AWWA, Denver, CO.
9. Water Distribution Training Course, 1962. AWWA Manual M8, AWWA, Denver, CO.
10. Water Meters - Selection, Installation, Testing and Maintenance, 1973. AWWA Manual M6, AWWA, Denver, CO.

POST-EVALUATION

1. True or False (2 pts. each)
   a. When a meter shows significant wear, it will tend to over register.
   b. Water hammer can cause severe damage to the system.
   c. Displacement meters are very accurate at low flows.
   d. When the water demand varies greatly a propeller meter should be used.
   e. Thermoplastic implies that a material cannot be softened after the initial formation.
2. What is tuberculation?
3. Name the five most common types of pipes in use today in distribution systems?
4. Name three factors that should be considered in determining the type of meter to use.
5. Name the five most frequently encountered service meters.
6. What is a service pipe?
7. A valve that joins a customer's service to the water main is called the:
   a. joint valve
   b. corporation cock
   c. bypass valve
   d. service valve
8. Name the three common methods used in disinfecting distribution systems.
9. What is the main disadvantage of the displacement meter?
10. When should you use a current or velocity meter?

ANSWERS

1. a. F
   b. T
   c. T
   d. F
   e. F

2. The pitting or growth of nodules inside the pipe.

3. Cast iron
   asbestos-cement
   plastic
   steel
   concrete

4. customer demand
   allowable pressure loss
   safety requirements

5. positive displacement
   current
   proportional
   compound
   fire service

6. Pipe running from the main to the customer

7. b

8. continuous feed
   slug method
   tablet method

9. high loss of head

10. When you have a large, sustained flow of water.

MODULE 14

SELF-INSTRUCTIONAL

Paul Hummel - NMSU

SAFETY

PREREQUISITES: Module Three - Analysis Procedure
Module Seven - Chlorination

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

1. True or False (20 pts. total; 4 pts. per question)
   a. Water treatment plant operators have less accidents than men who work for electric and gas utilities.
   b. Red Cross training in First-Aid has no bearing on prevention of accidents.
   c. Any injury should be treated promptly.
   d. Pumping stations, wet wells and chlorine rooms should be provided with adequate ventilation.
   e. A positive displacement pump can be started against a closed valve.

2. Which of the following does not apply when working with or in clarifiers. (4 pts.)
   a. Have non-skid surfaces on all steps, ladders or catwalks.
   b. Have a clean path to work on when working at the bottom of the structure.
   c. Life preservers should be worn by every one working on the equipment.

3. Guards should be put around all moving parts in (4 pts.)
   a. pumphouses
   b. clarifiers
   c. chemical mixing and feeding rooms
   d. all of the above

4. What is the first rule of safety: (4 pts. each)
   a.
   b.
   c.

5. From the following list, match the correct safety practice with the work areas listed. NOTE: Some work areas may have more than one safety practice associated with it. (60 total pts.)

8 pts. Pumping Stations:
8 pts. Clarifiers:
12 pts. Aerators:
8 pts. Chlorinator Rooms:
12 pts. Reservoirs:
12 pts. Laboratory:

SAFETY PRACTICE
a. adequate ventilation
b. guard rails
c. life preservers
d. proper labels
e. good housekeeping

ANSWERS

1. a. F
   b. F
   c. T
   d. T
   e. F

2. e

3. d

4. 1. Think Safety
   2. Act Safety
   3. Promote Safety constantly

5. Pumping Stations: a,e
   Clarifiers: b,e
   Aerators: b, c, e
   Chlorinator Rooms: a, e
   Reservoirs: b, c, e
   Laboratory: a, d, e

INTRODUCTION

In the other modules, you learned about the various aspects of your job. You learned about chemistry, microbiology, hydraulics and hydrology (surface and ground water) to name a few. All this knowledge, though, can not help you if you are unable to work.

But why would you not be able to work? You're strong, in fairly good health and barring a cold or some other sickness, you should be able to work the rest of your life. Maybe. Did you know that water treatment plant operators have four to five times as many accidents as electric and gas utility operators? Further more, the accident record of members of your profession is second only to mining operations. Water treatment seems to be a pretty dangerous occupation.

It doesn't have to be though. With the proper attitude toward your job, this accident record can be vastly improved. Read this module carefully. Know the procedures and recommendations offered here. It doesn't cover every aspect of safety but if you use the procedures recommended within and think safety, you will find other ways to lower the accident record of your profession. We want you to be able to work safely.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the following concepts:

1. General safety
2. Personal safety
3. Treatment plant and pumping station safety
4. Clarifier and sedimentation basin safety
5. Chlorination room safety
6. Collection and supply system safety
7. Laboratory safety
8. Fire prevention

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if you answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

SAFETY

The purpose of safety is to prevent accidents both on and off the job. Accidents can happen to anyone and at any time. And usually they are caused by someone's careless actions. Accidents can also be prevented. This is done only by you. You must think safety and act safety. It should be in your mind at all times.

In the water treatment business, an accident prevention program has five steps. The first step is to start and maintain an interest in safety. Hopefully this module will initiate this first step if you are not already safety minded. The second step is to maintain adequate injury records. This will help to know and recognize hazardous situations so that you can prevent further occurances of the situation. This leads to the third step. Locate and correct hazards. If equipment is malfunctioning, warn others with a sign and get it fixed as soon as possible. Make your job a safe place to work (Step 4). Keep your equipment in proper working order. Put it in its proper place. Handle it correctly. Step 5 is to control your work habits. Follow safety procedures and make sure your co-workers and visitors do the same.

REMEMBER:

THINK SAFETY

ACT SAFETY

PROMOTE SAFETY

YOUR JOB MAY DEPEND ON IT!!

HAZARDS

Working in the plant or in the collection system you will be exposed to many types of hazards. Below are listed some of the most common types of accidents.

Physical injuries are the results of some of the most common types of accidents encountered. Cuts, bruises, burns and broken limbs result from careless use of equipment. Use established safety procedures and handle equipment safely.

Unventilated structures can cause oxygen deficiency. Use fans or blowers to move air into structures you suspect may contain little or no oxygen or heavy gases such as carbon monoxide. Be especially careful in the chlorine storage area. Chlorine is very toxic so know and use proper procedures in handling this substance.

Be very careful in the laboratory when handling toxic or irritating chemicals. Use them only under a properly vented hood. Also be careful in handling potentially explosive gas mixtures both in the laboratory and in the plant. Keep open flames from areas where explosive gas mixtures may be present. Also provide adequate ventilation.

Serious injuries may result from fires. Store flammable materials in approved containers. Also know the location of fire fighting equipment and how to use it.

Another source of serious injuries is from electrical shock. Do not try to repair electrical equipment unless you know how to handle the equipment.

GENERAL SAFETY PRACTICES

The first rule of safety is think safety, act safety and promote safety constantly. This rule can not be stressed enough. You should know the safety rules of your plant and understand them thoroughly. You should wear the proper clothing and change them to meet the situation. Read any signs you encounter concerning the safe use of equipment. They will give you important information concerning safe load limits and unsafe conditions which may result in the improper use of equipment. Be alert to unusual conditions of equipment, unusual noises in the equipment, fumes, fire and other indications of danger. Correct any dangerous situations if possible or have someone that is acquainted with the situation or equipment correct it. Above all do not be afraid to ask for help. It may save someones life.

One should also be acquainted with proper first-aid. This can be done by taking a first-aid course offered by the Red Cross. It may seem as if this has no bearing on the prevention of injuries but people who know first-aid are less susceptible to accidents than those not prepared.

Not only should you be acquainted with first-aid but one should also use it. Any injury should be treated promptly, no matter how slight it seems. It may turn into something more serious. In case of serious injury, go to a physician immediately.

Have a properly stocked first-aid kit within easy reach at all times. Know where they are and how to use them. Also keep handy the numbers of the police, fire and ambulance service.

If possible, let someone know what you are doing and where you will be (checking basins, lakes, reservoirs, wells, etc.) If working alone follow a set routine, in that way if something should happen help could be provided sooner (your working habits would be known).

PERSONAL PROTECTION

As was mentioned earlier wear the proper clothing and equipment for the job you are doing. Wear hard hats, safety shoes, gloves or aprons if the situation calls for it. Eye protection is needed if working with a drill or lathe or while grinding, chipping, calking joints or breaking pavement with an air hammer. If working at night, carry a good working flashlight in case of power failure.

When toxic gases, vapors or dusts are present in an area that may be harmful, use the proper respiratory-protection equipment. Use gloves when handling weight and bulk, special gloves for dangerous articles, chemicals and tools. Keep your hands out of dangerous areas like machinery. Wash your hands after handling toxic materials.

Lift and carry loads properly. The rules for lifting and carrying are as follows:

1. Size up the load
2. Bend your knees
3. Get a firm grip
4. Lift with your legs
5. Keep your back straight
6. Keep the load close to your body
7. Face the load squarely
8. Raise and lower the load in the same manner
9. Wear proper protective clothing

Other ways to protect yourself from accidents is to keep floors clean, dry and free from unnecessary obstacles, make sure all work areas are properly lighted, know where safety equipment is kept (such as fire extinguishers, first-aid kits and respirators) and drive safely both on and off the job.

SELF-TEST

1. What are the three statements in the first rule of safety:	1. Think Safety 2. Act Safety 3. Promote Safety Constantly
2. Summarize the nine rules of lifting and carrying loads:	1. Size up the load 2. Bend your knees 3. Get a firm grip 4. Lift with your legs 5. Keep your back straight 6. Keep the load close to your body 7. Face the load squarely 8. Raise and lower the load in the same manner 9. Wear proper protective clothing

SPECIFIC HAZARDS

So far the module has covered general safety rules and procedures. Let us now look at safety procedures associated with specific areas in the plant, laboratory and collection system.

TREATMENT PLANTS AND PUMPING STATIONS

In rooms that contain pumps whether at the treatment plant or in pumping stations, make sure there is adequate ventilation. If the room is below ground and is provided with only forced air ventilation, make sure the fan is on before entering the room. Wear a safety harness with line when entering any underground structures such as below ground pump rooms, wet wells and tanks. One or more persons should also be present above ground to hold the rope.

Guards should be installed around all rotating shaft couplings, belt drives and other moving parts. These should not be removed unless the equipment is turned off at the main breaker. A warning sign should also be placed on the breaker. Replace all guards before starting the units.

Never remove or leave off equipment hatches unless you are actually working on the equipment. Provide barricades around the openings to prevent falls. Check all stairs in stairwells or ladders before using to make sure they are in good condition. If using a ladder make sure the bottom is seated properly so that it does not slip.

Never start a positive displacement pump against a closed valve. The yoke over the ball check could break on piston pumps.

All emergency and permanent lights should be of the type that is explosion proof. No open flames or smoking should be allowed in areas that may have an explosive atmosphere.

Keep the pump room clean. Remove all oil and grease and clean up spills immediately.

CLARIFIERS OR SEDIMENTATION BASINS

When working on clarifiers or sedimentation basins, watch your step. One of the greatest dangers in handling this type of equipment is the hazard of slipping. Make sure you have a good non-skid surface on all steps, ladders or catwalks. Be especially careful during freezing weather. Ice coatings on such structures can be very dangerous.

If a fire hose is used for cleaning, make sure to have two men holding the nozzle and a man on top to control the flow. A fire hose can be very dangerous.

When working on the bottom of a clarifier make sure you have a clean path to work on. Try not to work on sludge whenever possible.

As with the pumps in the pump house, guards should be put around all moving parts. Keep these in place while the unit is operating. Also make sure the drive unit of a clarifier is turned off at the breaker and is properly tagged.

Railings should be provided along all tanks at the tank side. If the structure is elevated make sure that there is a railing along the outside of the walk as well.

AERATORS

When working on tanks containing aerators, make sure you have someone with you. Also have life preservers located at strategic locations.

Guardrails should be installed around all tanks. As with clarifiers, if the tank is elevated also make sure guardrails are present on the outside of catwalks and ladders.

CHLORINATORS

Chlorine cylinders should be stored in a well ventilated room. Ventilation fans should be located at ground level. This is because chlorine is heavier than air. The room should be dry and cool with little direct sunlight shining into it.

Cylinders should be securely anchored. Large tanks should be blocked so they don't roll. Smaller ones should be stored strapped upright. Be very careful when moving them. Make sure they are secure before any moving attempts are made.

Make sure all connections to cylinders and tanks are secure and made with approved clamp adapters or unions. Check for leaks as soon as the connection is made. Even the slightest leaks become worse. If you smell chlorine in the chlorination room do not enter. Turn on the ventilation and seek help.

Post the number of your chlorine supplier and any emergency numbers in a conspicous place. More hints on chlorine safety may be found in the Chlorination module.

SELF-TEST

1. Any area that may be deficient in oxygen or contain toxic fumes should be adequately ________.	ventilated
2. Pumps should be turned off at the ________ ________ and a ________ ________ be placed there.	main breaker warning sign
3. In the pump house and at the clarifier guards should be put around all ________ ________.	moving parts
4. Did you read the safety procedures mentioned in the Chlorination module?	yes

COLLECTION AND SUPPLY SYSTEMS

Traffic Hazards

When working on pipes leading to the plant or customer's homes be especially conscious of safety. On streets or other traffic areas make sure the area is well marked and barricaded. Signs should be located far enough away from the work area to give adequate warning to drivers. Barricades should be arranged so that traffic flows smoothly around the work area without confusion. Warning devices such as flashing red lights or signalmen may also be needed.

Manholes

Many of the safety precautions mentioned in connection with other work areas apply to working in and around manholes. For example, check all ladders before entering the manhole. Make sure they are secure. Always check for an oxygen defiencency. Provide for adequate ventilation if necessary. Also make sure that you are working with at least two other people. This will assure help if a difficult situation arises.

In addition to these precautions, you should provide adequate warnings to the public as well as properly placed barricades. Use special tools to lift the manhole cover and place it flat on the ground two to three feet from the work area. Never use your fingers to lift it.

Wells

When constructing a new well, make sure the area is free of overhead or underground electrical cables before drilling. The public should not be allowed closer than 50 ft.

Check all machinery and equipment often to make sure it is in good operating condition. Stop all moving machinery while repairs are being made. Permit only experienced people to work on the dynamiting of wells. Keep all others away. Provide for adequate ventilation for all enclosures. Watch out for subterranean gases which may cause asphyxeations or explosions.

Provide adequate ventilation in well housings and make sure the building is locked except when in use. Allow only authorized persons to enter. Construct the housing of non-flammable materials.

Reservoirs and Lakes

LAKES AND RESERVOIRS ARE VERY DANGEROUS BECAUSE OF THE POTENTIAL OF DROWNING. BE CAREFUL. WATCH YOURSELF, YOUR CO-WORKERS, AND YOUR VISITORS.

At reservoir or lake sites you should be constantly aware of falling in the water. Life saving devices such as life rings and vests should be worn. Warning signs and guard railings should also be posted so that the public will not fall in. Watch for leaks in dam structures and defective machinery. Report them at once to your supervisor or if you have the responsibility repair them as soon as possible. If there is an indication of dam failure report it at once to the proper authority.

SELF-TEST

1. Barricades should be placed around work areas where there are traffic hazards so that there is not __________ in traffic patterns.	confusion
2. Use __________ __________ to lift manholes.	special tools
3. When dynamiting wells only __________ people should do the work.	experienced
4. What is the first rule of safety?	Think Safety Act Safety Promote Safety constantly

LABORATORY

The safety precautions listed below should be a review of what you learned in the Analysis Procedures (Module 3). Review the safety section of that module when you have completed this section of this module.

When working in the laboratory wear safety goggles or face shields when working with highly reactive chemicals or when heating materials. Use care when working with any glass equipment. Watch out for broken edges.

Make sure all bottles are properly labeled and that you select the proper chemicals for the test you are performing. Do not keep unlabeled or outdated containers in your laboratory. Never handle chemicals with your bare hands. Use a spoon or spatula for this purpose. Use thongs when heating laboratory ware.

Make sure the laboratory has adequate ventilation. If you are working with poisonous, irritating or explosive chemicals or mixtures, work with them under a hood.

Never use the laboratory as a kitchen. Even the cleanest laboratories have enough residual chemicals from spills lying around that one can become very sick from their contamination of food. Laboratory glass ware should not be used for coffee cups or food dishes.

Remember to add **ACID** to **WATER. NEVER THE REVERSE.**

SELF-TEST

1. Bottles should be __________ properly.	labeled
2. Poisonous, irritating and potentually explosive chemicals and mixtures should be worked with __________.	under a hood
3. Always add __________ to __________. Never the reverse.	Acid, Water
4. Did you read the Analysis Procedures Module?	yes

FIRE PREVENTION

Oil and paint-soaked rags, smoking in areas near explosive or flammable gases and shorts in electrical equipment can lead to property and personal damage due to fire. Keep your work areas clean and neat. Put all oil and paint-soaked rags in metal containers. Observe no smoking signs and watch for shorting equipment. Good housekeeping will prevent fires.

If a fire should break out and it is small enough to be controllable, use a fire extinguisher to put it out. Module 3 tells the type and kinds of extinguishers. Know where these are located as well as the number of the nearest firestation. If the fire is too big for you to handle leave the building immediately. Do not stop to get anything. Just leave.

SUMMARY

This module does not contain all the safety precautions you can and should use. What it does do is give you a place to start. Read as much as you can about safe use of equipment as well as general safety practices. This can be done in part by reading the books listed under suggested readings.

REMEMBER:

THINK
SAFETY

ACT
SAFETY

PROMOTE
SAFETY

YOUR JOB MAY DEPEND ON IT!!

SUGGESTED READINGS

If you wish to find further information on the topics discussed in this module, the following books are recommended. The page numbers refer to the topics discussed in this module which are found in that book.

1. Basic Level Water Treatment Operator's Practices, AWWA No. M18, AWWA, New York, NY p. 129.
2. Operation of Wastewater Treatment Plants, California Water Pollution Control Association, Environmental Protection Agency, Sacramento, CA Chapter 12.
3. Safety Practice for Water Utilities, AWWA No. M3. AWWA, New York, NY p. 128.

POST-EVALUATION

1. True or False (4 pts. each)
   - a. Safety is not important in the laboratory.
   - b. Sandals can be worn when performing chemical tests.
   - c. The accident record of water treatment plants is second only to the mining industry.
   - d. Accidents are usually acts of God.
   - e. The purpose of safety is to prevent accidents only on the job.
   - f. The first step in a safety program is to start and maintain an interest in safety.
   - g. Chlorine is not toxic.
   - h. One need not pay attention to unusual conditions of equipment or unusual noises.
   - i. Wear the proper clothing to meet the situation.
   - j. Never start a positive displacement pump against a closed valve.
   - k. Ice coatings on clarifiers or sedimentation basins are not dangerous.
   - l. Manholes can be lifted with your fingers.
2. List the nine steps in properly lifting and carrying objects. (4 pts. each step)
3. When constructing a new well make sure the area is free of __________ before drilling. (4 pts.)
   - a. rocks
   - b. overhead or underground electrical cables
   - c. underground water
4. Name the first safety rules: (4 pts. each)
   - a.
   - b.
   - c.

ANSWERS

1. a. F
   b. F
   c. T
   d. F
   e. F
   f. T
   g. F
   h. F
   i. T
   j. T
   k. F
   l. F

2. 1. Size up the load
   2. Bend your knees
   3. Get a firm grip
   4. Lift with your legs
   5. Keep your back straight
   6. Keep the load close to your body
   7. Face the load squarely
   8. Raise and lower the load in the same manner
   9. Wear proper protective clothing

3. b

4. a. Think Safety
   b. Act Safety
   c. Promote Safety constantly

MODULE 15

SELF-INSTRUCTIONAL

Peter J. Sireno - NMSU

PUBLIC RELATIONS

PREREQUISITES: None

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Evaluation at the end of the module. If you score 70% or better you may go on to the next module. NOTE: There are very few questions on the State Exam on Public Relations. The information contained in this module is important but falls within the category of good common sense and "nice to know" rather than technical information that is essential to perform the technical aspects of your job.

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SELF-EVALUATION (10 points each answer)

1. True or False
   - a. As a part of Public Relations, we should let the Public know about water plant operations.
   - b. The reliability of water supply has no effect on fire insurance rates.
   - c. One justification of the cost of softening hard water is its savings to the consumer in soap costs.
   - d. It is totally the responsibility of management to develop, design, and implement a Public Relations plan.
   - e. A Public Relations Program is nice but not essential for effective water utility operation.
   - f. According to dental experts, children who drink water containing about 1.0 ppm flouride during the period of tooth development will have considerably less dental decay than those children using flouride-free water.
   - g. A formal Public Relations plan need not be continuous.
2. If the laboratory results show a "bad" sample, the next step is to:
   - a. cut off the water where the sample was taken.
   - b. take another sample.
   - c. notify the people to start boiling water.
   - d. disregard it.
3. A customer's meter shows very little change from the previous reading with the water in continuous use. Would you:
   - a. bill him for the meter reading.
   - b. recheck the meter.
   - c. bill him for the previous month's reading.
4. Public Relations is:
   - a. nice but not very important.
   - b. the responsibility of management and therefore should be of no concern to other employees of the utility.
   - c. if very important, should be initiated by management and implemented by all employees of the organization.

ANSWERS

1. a. T
   b. F
   c. T
   d. F
   e. F
   f. T
   g. F

2. B

3. B

4. C

INTRODUCTION

We can define Public Relations for water utilities as a process of communications between the water utility and the community for the purpose of building good will in the community. In other words the purpose of Public Relations is to keep the public informed of ongoing efforts to bring them the best quality water possible as well as establish credibility as an honest, professional representative of the water supply industry. It is the manager of the water utilities who is in the key position to assure that the water utilities Public Relations activities are effective. The primary reason for publicizing the activities of the water utility is that the utilities manager has a definite responsibility to furnish the public (taxpayers) with complete and accurate information concerning the utilities needs, activities, and accomplishments.

The direction of a public relations program must also begin with the utilities manager or an employee who reports to the utilities manager. Only when the person responsible for the Public Relations Program is in a position to influence policy and bring it in line with Public Relations Objectives can the program be really successful. It is important for the reader to note that each water utility must develop a Public Relations Plan that is individually suited to its needs. Equally important is to understand that although the Public Relations Plan starts with and is coordinated by the utilities manager or his designatee, success of the Public Relations Plan can only be achieved if all employees of the water utilities are:

1. Informed on the total Public Relations Plan.
2. Actively involved in the implementation of one or more aspects of the Plan.
3. Recognize that the successful Public Relations Program never ends - it is continuous.
4. Actually involved in continuous evaluation of the existing plan providing input for deletion and/or additions to the plan.

In other words a successful Public Relations Program can only be achieved if all employees are not only knowledgable of the program, its purposes and plan of action but are willing to accept responsibility in its implementation.

PERFORMANCE OBJECTIVES

The performance goal of this module is to plan a calendar of Public Relations activities for one year and be able to successfully implement each activity. At the conclusion of this module you will be able to:

1. Design a calendar of Public Relations activities for one year.
2. Prepare a newspaper article for publication.
3. Know the techniques of discussing the water utilities function before interested groups in the community.
4. Prepare a brochure for your program.
5. Develop a list of media contacts in the community.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if your answer is correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

BENEFITS OF PUBLIC RELATIONS

Public Relations includes everything from answering the telephone politely; handling complaints and requests; billing and collection techniques; reading meters; establishing rates; establishing new accounts; installation, maintenance and repair; main extensions; personnel policies; and treatment changes. To benefit from Public Relations, all employees generally must be constantly aware that Public Relations is an integral part of their whole effort; it is not just something nice to do but something that must be done.

Public Relations will improve communication and cooperation between the water utility and its publics, as well as broaden their understanding for the utility. By making your activities public, you will attract interest among potential employees. It will also give all employees reasons to have pride in their work. You can be sure that a good Public Relations effort will also produce goodwill and a favorable element within the community.

A good Public Relations program doesn't just happen, it must be carefully planned. To receive the greatest benefits from Public Relations, you will need to develop goals and objectives for the program. You may wish to consider the following.

ESTABLISHING GOALS

Goals are usually broad statements which help establish the guidelines with which an organization can work within. For instance one goal may be: "to keep the public informed of on going efforts to bring them the best quality water possible or to establish credibility as an honest, professional representative of the water supply industry."

DEVELOPING OBJECTIVES

Objectives are specific statements that detail exactly what is going to be achieved. It is important to note that objectives must be 1) achievable; 2) measurable - to show what has been accomplished; and 3) should include a specific period of time when the objective will be achieved.

An example of an objective may be "to develop a brochure in one month to be sent with the next billing which will inform customers of exemptions, variances, or violations to the Safe Water Act (PL 93-523)." Probably the best way to implement a good Public Relations program is to establish an organizational policy to treat employees, customers and the general public fairly, honestly and respectively. In other words, we should treat others as we would like to be treated. If we do this all, our "publics" will be the best Public Relations tool we will have at our disposal. Think about it, employees who are treated fairly in terms of wages, hours, real opportunities for advancement and who are well informed about the organizations purposes, plans and practices couldn't help but be a positive influence on the organization's image within the community.

The same common sense principal applies to our customers and the public in general. Customers should be treated politely, with interest and consideration. Whether we are a meter reader or the day supervisor, during our contacts with customers or the general public, we are the utility company to them. Will their impression of the utility be . . . nice, polite, considerate, helpful and fair or will it be rigid, unconcerned, rude and snappish.

SELF-TEST

True or False

1. Public Relations is nice but not essential for the successful operations of a Public Water Utility.	False
2. It is the responsibility of management to design, develop, and complement a Public Relations Plan. Therefore since I'm not a part of management it is no concern of mine.	False
3. Everyone working for a water utility must be knowledgeable of and willing to accept responsibility for its implementation for the success of a Public Relations Plan.	True

NOTE

The following information is presented only to assist the reader in developing a Public Relations Plan, conducting interviews, and/or developing promotional brochures. It is not essential for certification.

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DEVELOPING PUBLIC RELATIONS MATERIALS

Writing a News Release

There are five points important to a good news release: WHO, WHAT, WHEN, WHERE, AND WHY. If possible, a sixth, HOW should be included.

It is very important to get these points in the first sentence or two. These first sentences are called the lead. A good lead captures the reader's or listener's attention and makes him want to know more.

Now go into the details of the story. Each succeeding paragraph should be of declining importance. Professionals call this writing technique the "inverted pyramid." This permits the editor to pick up the important facts of the story in the first few lines. Then, if he doesn't have room for the entire story, he can cut from the bottom. This is true of both print and broadcast media.

Use short words. Write short sentences, short paragraphs. Two sentences make a good paragraph in a news release.

Be brief. Almost every news release can be written on one or two double-spaced typewritten pages. Two pages double-spaced will fill about 12-inches one newspaper column wide. This is a lot more space than most editors can give one item.

Always give exact date in a news release: "June 10" rather than "next Thursday" or "tomorrow". Specify "October", not "next month". Double check date of day and week on a calendar.

List the address as well as the name of a meeting place. Remember, you are writing for people you do not know.

Never use a word in a news release that you would not use in everyday conversation. Never use a ten-cent word if you can think of a good five-cent word.

Forget all about adjectives when you are writing a news release. Don't say a speaker was dynamic. If he was worthy of special mention, relate what the speaker had to say that was memorable.

Figures in your story? Always spell out numbers from one to ten, then use numerals from 11 on up. Never begin a sentence with numerals.

When you have finished the draft of your story, go over it and cross out all the adjectives like "the, a, and an". Check every point of your story for accuracy. Never guess on dates, time, places, or names.

Never include a telephone number. News copy goes through many hands and the chance of error is great. Also, when you list a phone number for ticket sales and the like, editors realize you are using their columns for free advertising. They sell space and time for such a purpose. Never mention door prizes, raffles or lotteries in a news release. Newspapers are sent through the U.S. mails, and the law forbids their use of such news.

If pictures are included, make sure to include the names of everyone that appears in them. Smaller prints have a better chance to be placed in the newspaper than larger ones.

Traditionally, there have been hard and fast rules for the use of names. With the change of times and the introduction of Ms., it is suggested that you check with your local paper, radio or T.V. station to find out how they prefer to see names written.

Finally, ask yourself: If I were not an employee of the water utility would this news interest me? If the answer is No, tear it up. If the answer is Yes, you are ready to type your news release.

When typing the news release remember the following:

1. Use 8½ x 11" plain white paper.
2. Always send editors an original--carbon copies smear easily.
3. When sending identical releases to several places, list the places at the top of the release.
4. Keep a copy of every release sent out.
5. Leave margins of at least 1½ inches on each side.
6. Give full reference data on upper left hand corner; this can be single spaced.
    a. Water utility's name
    b. Your name
    c. Street and City address
    d. Phone number
7. Type release date in upper right hand corner; when possible type "For Immediate Release."

8. Start typing 1/3 way down the first page if it continues for more than one page.
9. Type double or triple space on only one side of paper.
10. Type "More" at the bottom of page if it continues for more than one page.
11. Type # # # # or * * * * under final paragraph.
12. Don't staple pages together.
13. Each page should end with a complete paragraph. Do not end a page in the middle of a sentence of paragraph.

These are basic rules--check with individual papers to be sure how they want things done.

Radio and Television

Air time is extremely valuable. To merit a share of the crowded air time for your program, your news must appeal to a widespread audience.

Broadcast time is limited by the clock; newspapers can expand their page numbers to conform to the needs of the day. But radio and T.V. Stations are limited to the hours they are licensed to be on the air. Thus, competition for air time is even more intense than for newspaper space.

Study the programs of your local stations before you make your first station contacts. List the ideas you have for various shows which reach the audience you need to influence. Here are a few possibilities:

1. Live or transcribed (recorded) interviews.
2. Music programs laced with local news.
3. Panel or group discussions.
4. News items in the form of community bulletin board or town-crier format.
5. Editorials which present the station's support of community-wide programs or projects.

Remember, the program director will make all final decisions as to what goes on the air, but will welcome your ideas and suggestions.

Your best contacts are the program director and the news director. They coordinate the public service time.

Always telephone in advance to find the best time to call in person. Then be friendly, but brief when you visit these busy people.

Tell them about the utility company and the message you would like to confer. Ask for their cooperation by giving your newsworthy items air time. Do they have interview shows for representatives of the Water Utilities Industry. Will they tape record feature shows in advance of broadcasting? How do they like to have news releases prepared? Make careful notes of all these important answers.

Meeting deadlines and prompt appearance for live or taped shows cannot be stressed too much in your work with the broadcast industry. News that is not received on time is lost forever. It is extremely important for persons appearing on live or taped shows to arrive well in advance of the hour set. Station personnel haven't a moment to spare!

Follow station suggestions for selecting people to represent your utility on the air. For a radio show they are likely to suggest a person with a pleasant speaking voice, not given to nervousness.

Be sure the person is well-informed on the subject to be discussed. A series of small cards with pertinent data--day, hour, place, purpose of meeting or project, and other highlights--offer a form of mental insurance against momentary lapses of memory.

T.V. appearances require the talents outlined above plus a few basic rules of dress. Suits or dresses of soft - medium colors or pastels are best. Sharply contrasting patterns and colors, noisy bracelets, sparkling or highly polished jewelry are very bad. Go light on make-up. Don't worry about glasses. The crew can arrange lighting accordingly, so if you need glasses, wear them.

When you write for radio and television, the same basic rules apply as in newspaper copy. Be brief, accurate, neat. The style of broadcast news releases vary slightly. Check with your station program directors to see how they want copy prepared.

Guide for Conducting a Press Conference

First, make sure you have something significant to say or do that would warrant a press conference. A kick-off press conference marking the start of a bond issue certainly has merit, especially if you have the Mayor doing the kicking. But you wouldn't ordinarily call a press conference to announce that some employees have passed their High School equivalency exam.

Once you decide to hold a press conference, here are some suggested guidelines:

Start planning at least two weeks in advance. Decide what the news is, who should announce it, and when. Contact the principals immediately to get their commitment and input.

In setting the specific day and time for the press conference, familiarize yourself with the deadlines of the major news media you hope to attract to the news conference. For example, if you hope to make a splash in an afternoon newspaper, you'd probably hold the conference early in the morning. But check, because your local situation may be different.

Decide who you want to invite besides the news media. Usually, you invite key people in your local government, federal agency, and business community.

Send a written notice to the news media at least a week in advance of the news conference along with a brief description of the purpose of the conference. Better still, have an employee hand deliver the notice and be prepared to explain the reason for wanting to call the news conference. VERY IMPORTANT! Follow up with a phone call to the media the day before as a reminder.

Have prepared text or news release of the announcement to be made, particularly if statistics are involved. Sometimes a summary of the key points will suffice. But something in writing will be helpful to the news media and help avoid errors.

Work up a written agenda so that everyone knows his role--who does the introduction, who makes the announcement or cuts the ribbon, etc. Everyone involved should know his role. The news media should be able to identify all participants.

If you prepare a public information packet for the news media, include with the text or release a copy of brochures and other documents giving background information about water utility. Even if you don't have a packet, make sure those documents are on display and available in the main office, along with audio-visual and other informational materials.

If appropriate, have employees either present or be involved in the conference. Employees are the "utility" to the public and are the best public relations we have; keep them out front whenever possible.

If you expect T.V. coverage, take that into account when you map out the physical arrangements...where the principals will be, where the press will be, where the electrical outlets are, etc.

Arrange to have photographs taken.

If you have any electronic gear (microphones, tape recorders) make sure they are tested in advance.

Start on time. The media probably have other assignments to cover.

It's a good idea to tape record the proceedings.

Try to predict questions that might be asked and prepare for them.

Don't let the program last too long. Again, the media have other things to do. Make the announcements, handle any questions that may arise, and then end it.

Make sure you send the Missouri Department of Natural Resources office copies of any clippings or a photograph for use in the newsletter.

Group Presentations

The purpose of public relations as a part of the managers job is to create interest and support for the utility. One very effective way of promoting the utility is accomplished by the manager talking informally or formally about the program.

Formal presentations to large or small groups of people in the community may be the best way of reaching a large number of people and explaining the utilities needs, activities and accomplishments. The manager who is willing to speak before large groups about the utility may find himself in great demand. To aid in preparation for these types of activities, the manager should keep on file visuals, topics, and outlines of different talks.

Even though he may have an outline of a talk, he should take into consideration the specific group to whom he is speaking. A topic for the talk and the specific objective of the talk should receive special consideration. Different groups to whom might give talks include: merchants, owners, operators, managers; local, state and national associations; social and civic groups; employees, and shareholders. If a particular presentation is especially successful with a group. The manager should make special note of this and be sure to keep the outline. The manager who is always prepared, even on the spur of the moment, will be remembered.

Use these guidelines when preparing your presentation:

1. Select your subject.
    a. Tailor to common interest of group if you know them.
    b. Take subject of strong general interest if you do not know them.
    c. Adopt a manner of presentation suitable to your audience.
2. Outline what you will say.
    a. Follow a general thesis throughout all components of your presentation.
3. Develop the outline.
    a. Fill in details.
    b. Supply suitable examples.
    c. Revise until it's good.
    d. Plan visual and/or auditory aids.
4. Test the outline.
    a. Stand up when you practice.
    b. Add materials from your sources if not long enough.
    c. DO NOT MEMORIZE--speak from ideas.
    d. Express feelings--gesture.
5. Deliver the speech.
    a. Look at the audience before you begin.
    b. Stand straight and walk straight.
    c. Vary rate of talking.

   - d. Speak louder than normal.
   - e. Pronounce clearly and carefully.
   - f. Sum up talk in one sentence or less.
   - g. Take last look at audience when through.

6. Review the speech.
   - a. Decide on what improvements could be made.
   - b. Judge effectiveness of material.
   - c. Set goals for next attempt.

Brochure and/or Bullentin Board Announcement

In order to inform the necessary people about your utility it is essential that you be able to develop and assemble an effective brochure. A brochure is a type of communication media that is prepared and directed at customers, employees, shareholders, and civic groups. It is usually a one page fold-out that contains information about the utility and its operations in the community.

When developing a brochure for your company, it is necessary to begin with an outline of the information you wish to include. The information you select should be accurate and up-to-date. It should be written clearly and organized in a manner that will keep the brochure as simple as possible. During the writing process, you should constantly keep your reader in mind to insure that the selection of information is appropriate and interesting to him. Eliminate technical jargon as much as possible so that the brochure will be easy to read and understand.

In order to design an attractive and interesting brochure, you should:

1. Make the introduction of your brochure interesting. You may entice your readers with a catchy headline, or an appropriate illustration, or both. It should attract your reader's attention and invite them to read further.
2. When arranging your information on paper, you should avoid making your brochure look lengthy and overcrowded. Allow at least one-half inch margins at the top and bottom and one-fourth inch margins at each side of the pages or columns. When used appropriately, spacing can be used to add emphasis and attractiveness to your brochure.

3. The size and style of print you select for your brochure can also add interest and emphasis to points you wish to stress. The heading print on the first page of your brochure should be at least three-eighths inch tall. The introductory heading size will probably need to be taller than the remaining heading in your brochure for it will hold major emphasis. The style of print should be carefully considered because it will also contribute to the image you display with your brochure.

4. Brochures that are printed in color usually attract more attention than those printed in black and white. It is more often true that the more color on your brochure the more attention it will attract. However, color can be overused. Basically, colors may be classified into two groups--warm and cool. The warm colors, red, yellow and orange, appear to advance, while the cool colors of violet, blue and dark green appear to recede. When selecting a colored background for your brochure, cool colors will provide a three-dimensional effect, making dark print appear to stand out on the page. You will need to keep in mind the qualities of color and the image they will present on your brochure to your readers.

5. Photographs can also be an effective addition to your brochure. They will add interest and attractiveness as well as provide emphasis to areas of importance. Avoid selecting photographs that are dark or very detailed because they may not print clearly. Pictures that are close-ups on plain background are preferred. When including pictures in your brochure, you will need to consult the publisher about the quality you will be able to obtain from them. Pictures will usually print clearest on smooth, slick paper. However, this type of paper is more expensive than rougher, more textured paper.

The budget allotted for printing your brochure may be limited. Therefore, it is necessary for you to determine the value of some of the more expensive elements that you may want to include.

1. Pictures can be an expensive element in a brochure since they require better quality paper and are costly to reproduce. However, they are valuable in that they can often express an idea better than words.

2. Color is an important motivational factor but using two or more inks is an added expense when a similar effect can be achieved by the use of one ink and colored paper.

3. Additional expense can be avoided by ordering enough brochures the first time, preventing expensive reorders.

Once you have determined the information to be included in the brochures you are ready to begin experimenting with its assembly. Arrange and rearrange the appropriate information, headings, and drawing following the principles discussed on style and size of print, spacing, and color.

After you have decided on the appropriate layout, you are ready to begin finalizing it. Position and paste the major elements of the layout first to ensure proper spacing for the assembly of your remaining information.

When you have finished your basic rough layout, you are ready to consult the publisher about additional considerations for the brochure such as color of ink, type of paper, and other details. In order for your brochure to be as effective as possible, it should be given a great deal of thought and display creativity and originality. Do not print the same brochure year after year, changing only the dates or color.

Your brochure should provide a means through which you can communicate a fresh approach to both the water utility industry and your specific utility and stimulate reader interest.

Basic B's For Publicity

1. Be the only person from your group to contact news media. Two members calling the same newspaper editor or program director are bound to bring conflict or confusion.
2. Be quick to establish personal contact with the right persons at each newspaper, radio, and television station in your area.
3. Be sure to write everything down. Train your memory, but don't trust it.
4. Be prompt in meeting every deadline.
5. Be legible. Type news releases. Erase and correct errors. Don't use carbons, except for your own copy.
6. Be accurate. Double check dates, names, places before you submit your copy.
7. Be honest and impartial. Give credit where due.
8. Be brief. Newspaper space and air time are costly.

9. Be brave. Don't be afraid to suggest something new if you honestly believe you have a workable idea. Media people welcome original ideas when they're practical and organized logically.
10. Be business-like. Never try to obtain publicity by pressure of friendship or business connections. Never ask when a story will appear. Never ask for clippings.
11. Be appreciative of all space and time given the water utilities' publicity. The media giving it also have space and time for sale.
12. Be professional. Members of the press are always invited guests. Never ask them to buy tickets or pay admission. Arrange a special "Press Table" for large banquets.

PUBLIC RELATIONS CALENDAR

A public relations calendar is a list of all public relations activities for your organization for one year. By using a calendar you will be able to budget your time wisely, prevent overlooking any essential public relations activities, and achieve your public relations goal.

Although the responsibility for setting up and following a public relations calendar should lie entirely with the utilities manager, the following discussion is worded with the assumption it is or will be your responsibility. (You should obtain as many suggestions on public relations as possible from those who can contribute--citizen advisory committee, supervisors, and employees). From these ideas and suggestions, you must select those activities that are most relevant to accomplishing the public relations goals. However, your calendar must not require so much attention that you cannot devote sufficient time to the other areas of your job.

When compiling your list of public relations activities it is helpful to write a specific objective and list the activities you will be considering. This will provide you with a list to use when selecting the activities to place on your calendar.

Your public relations activities should be set up as an actual calendar with activities listed by month. When planning your public relations calendar you should:

1. Use a variety of media
    a. Local newspapers
    b. Area weekly newspapers
    c. Speakers--for example, local service clubs
    d. Trade journals
    e. Educational magazines
    f. Bulletins & pamphlets
    g. Handbills
    h. Television
    i. Radio
    j. Posters

2. Capture various audiences
    a. The public at-large
    b. Business community
    c. Public officials
    d. Customers
    e. Public and private social agencies
    f. Shareholders
    g. Employers
    h. Employees

3. Publish information on various areas of the organization
    a. Main extensions
    b. Treatment changes
    c. Gate changes
    d. Emergency maintenance and repair schedules
    e. Placement on the job
    f. Success on the job--raises & promotions
    g. On-the-job training
    h. Progress toward completion of AWWA or MWWA instructional programs
    i. Success of individual employees
    j. Employer Appreciation Banquet
    k. Completion of State Certification Exams

4. Delegate responsibility & authority to employees to help develope pride; the organization activities

Sample Calendar

January

1. Prepare brochures and posters on services provided by your utility.
2. Arrange window displays in downtown stores or career opportunities.
3. Newspaper article current and future activities of the utility.
4. Publicize the AWWA or MWWA.

February

1. Arrange for employee presentation at local businessmen's meeting to promote utility (or a bond issue etc.).
2. Conduct Consumer Attitude Survey or other community project and follow-up with publicity.
3. Radio or T.V. interview with state or National EPA and/or Fresh Water representative event winners.

March

1. Announce plans for Employer Appreciation Banquet.
2. Publicize result on Consumer Attitude Survey.

April

1. Newsletter article on Advisory committee.
2. Publicize Employer Appreciation Banquet.
3. Prepare a flyer to be sent out with customer billing.

May

1. Interview on T.V. or radio on changes in Safe Water Legislation.

June

1. Employee appearance and presentation at local civic clubs.
2. Guest speaker.
3. Call meeting of appropriate employees to determine ways to improve billing and collection techniques.

July

1. "Employees on the job" article--radio program using associates.
2. Publicize any changes in billing and collection technique.

August

1. Letter to shareholders and businessmen inviting them to an open house.
2. Newsletter article on the advisory committee.

September

1. Visit Chamber of Commerce and seek assistance for a consumer attitude service, water conservation or similar activity.
2. Open House and article.

October

1. Field trip to business before Christmas.
2. Publicize MWWA instruction.
3. Fall picnic for employees.

November

1. Employee appearance and presentation at local civic clubs.

December

1. Christmas breakfast for employees.
2. Mail Christmas cards.

SUGGESTED READINGS

If you wish to find further information on the topics discussed in the module, the following books and articles are recommended.

1. Basic Water Treatment Operator's Manual, 1971. AWWA M18, AWWA New York, NY Chapter XVI.
2. Water Utility Management, 1959. AWWA M5, AWWA Denver, CO Chapter 21.
3. Spangler, Robert M. "Public Relations Basics", This is a flyer put out by the AWWA. Mr. Spangler is the Director of Public Information for the AWWA.

POST-EVALUATION

1. List the three essential criteria for a good well-stated objective.
2. List the five points for a good news release.

True or False

1. It is not necessary to prepare for a Public Relations Program on radio or television as nothing has to be written down as for a newspaper article.
2. As a part of Public Relations, we should let the public know about water plant operations.
3. The reliability of water supply has no effect on fire insurance rates.
4. One justification of the cost of softening hard water is its savings to the consumer in soap costs.
5. It is totally the responsibility of management to develop, design, and implement a public relations plan.
6. A Public Relations Program is nice but not essential for effective water utility operation.
7. According to dental experts, children who drink water containing about 1.0 ppm flouride during the period of tooth development will have considerably less dental decay than those children using flouride free water.
8. A formal Public Relations Plan need not be continuous.

Multiple Choice

1. If the laboratory results show a "bad" sample, the next step is to:
   a. cut off the water where the sample was taken
   b. take another sample
   c. notify the people to start boiling water
   d. disregard it
2. A customer's meter shows very little change from the previous reading with the water in continuous use. Would you:
   a. bill him for the meter reading
   b. recheck the meter
   c. bill him for the previous month's reading
3. Public Relations is:
   a. nice but not very important
   b. the responsibility of management and therefore should be of no concern to other employees of the utility
   c. is very important, should be initiated by management and implemented by all employees of the organization

1. If time allows you may wish to prepare a news article for your local newspaper using the principles discussed in this section. Have other members of the class and your instructor check the article to see if it is appropriate as a Public Relations Article and meets the essential criteria outlined in the module.

ANSWERS

1. achievable
   measureable
   specific time for completion
2. who
   what
   when
   where
   why
   (how)

True or False

1. F
2. T
3. F
4. T
5. F
6. F
7. T
8. F

Multiple Choice

1. B
2. B
3. C

MODULE 16

SELF-INSTRUCTIONAL

Peter J. Sireno - NMSU

MANAGEMENT

PREREQUISITES: None

DIRECTIONS: Take the Self-Evaluation following these directions. If you score a 90% or better on it, you may go on to the next module. You may wish to go through this module though, to review the material. If you scored less than 90%, study the contents of this module carefully and take the Self-Tests at the end of each section to see how you are progressing. If you cannot answer the questions, study that section again to become more familiar with the material presented in it. After you have studied this module take the evaluation at the end of the module. If you score 70% or better you may go on to the next module.

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SELF-EVALUATION

True or False (10 pts. each)

1. Most of the primary supervisory functions are conducted relatively infrequently by plant supervisors
2. Planning means assigning tasks to the right people.
3. A standing policy may be thought of as a plan, just as a schedule may be thought of as a plan.
4. Organizing involves developing a systematic method for predicting future events.
5. Reports and control are synonymous terms.
6. Control means taking corrective action.
7. Reports, ideally, should reflect either the most optimistic, or the most pessimistic view of the area covered.

Fill-In (30 pts.)

1. Explain the importance and need for records.

ANSWERS

1. F
2. F (directing)
3. T
4. F (planning)
5. F
6. F
7. F

Fill-In

1. Records are important to:
   a. Document plant performance, efficiency, and problems
   b. Justify budget requests
   c. Provide design criteria for remodeling, expansion, and new processes
   d. Verify observations of plant operation
   e. Help if legal action is threatened
   f. Document quality of receiving waters
   g. Report preparation for supervisors and regulatory agencies
   h. Identify significant departures from normal values and take corrective action
   i. Show type and frequency of maintenance of operating units

INTRODUCTION

Many supervisors or managers today come from rank and file employees. Contrary to popular belief there is a sharp difference between being able to effectively perform an operative job and being able to effectively perform in a managerial position. This module will present basic information on the responsibilities (functions) of supervisory personnel. Although you may not presently be in a supervisory position, it is important for you to recognize the responsibilities of your supervisors. Even more important is that you as an employee may be presently performing some or all of the supervisory functions that are presented. Much of the material used in this module was taken from the Publications "Basic Water Treatment Operator's Manual published by the American Water Works Association, "Manual of Instruction for Water Treatment Plant Operators" published by the New York State Department of Health, Office of Public Health Education and Operation of Wastewater Treatment Plants, published by Environmental Protection Agency.

PERFORMANCE OBJECTIVES

When this module is completed, you will be able to show that you have mastered the following concepts:

1. The Four Basic Functions of Management
2. Identification of common problems encountered by the plant supervisor
3. How to develop and prepare reports and records on plant operations

Mastery of this module will be shown by answering the questions found in the Post-Evaluation.

INSTRUCTIONS

Read each section carefully. Make sure you understand what each section is saying before moving on to the next section. Look up any unfamiliar words in each section. The Self-Tests are designed to review what you have learned in the previous section. To use the Self-Tests, cover the answers on the right side of the page until you have answered the question. Then move the cover down to see if you answered it correct. If you can answer all of the questions at the end of each section in the Self-Test and you understand the content of the section, go ahead to the next section. Your instructor will answer any questions you have or you may look them up in one of the books listed at the end of this module. If there is a laboratory connected with this module, your instructor will provide you with instructions.

FUNCTIONS OF SUPERVISORY MANAGEMENT

Many textbooks, articles, and pamphlets have been written on the major functions (responsibilities) of management. The basic functions usually presented are planning, organizing, directing, controlling, motivating, communication, delegating, and staffing. For our purposes we will be concerned with planning, organizing, directing, and controlling as these are the functions normally associated with supervisory positions.

Supervision is achieving desired results through the efforts of others. As a supervisor, you do not do operative work yourself. You assist the operative employee. You suggest to them how to do it and see to it that they have the materials and tools necessary to perform the task at hand. Your main responsibilities are to create a work environment conducive to the employee's personality in a manner that provides challenge, interest, and satisfaction. By doing these things you not only will encourage the growth of the employees' personal abilities but will aid toward achieving both organizational goals and individual goals.

PLANNING

Planning,as the name implies, involves looking ahead, using factual information and experience in order to decide on a future course of action to follow in order to achieve a desired result. Planning involves developing and selecting the policies, objectives, programs, and procedures for achieving them for the entire organization or a department within that organization. It involves forming a course of action for the future - either short term or long term. Although we are mainly concerned with developing a short term plan, the same approach is used to develop a long term plan. Although common sense tells us that many things can happen over a long period of time which would make a long term plan useless, long term plans establish the boundaries for our short term plans and provide us with direction.

In other words, planning is the selection of a specific course of action from various alternatives of policies, objectives, procedures and programs. The plan will be carried out by the supervisors and other employees of the organization.

It is important to note that planning does not have to be formal; it can be done by inexperienced supervisors and should always be intergrated with all who are involved.

Basic Essentials for Planning

Below is a list of items that are essential for developing meaningful and workable plans.

1. The planner must understand what the organization wants to achieve or what is the problem.
2. The planner must know how things are now within the organization before he can plan how they ought to be.
3. The plan must be developed so it is compatible to the organization and the needs and requirements of the employees in that organization.
4. Plans must be communicated so all who will have a part in its implementation understand the plan, what is to be achieved, and the procedures to follow for implementation.
5. Each component of the plan must have a realistic but definite completion date.
6. Short term plans should be precise and operational.
7. Long term plans should be written as guides to action and not as definite operational strategies.
8. All plans should have alternative courses of action to allow for unexpected circumstances.
9. In brief, plans should answer a) what is going to be done b) why c) when d) by whom and e) how.

Why Plan

Planning helps gain the kind of coordination needed to assure that a task will get done and be done well. Planning also helps the manager when things may not get done or may not get done right or where there is a duplication of effort.

Advantages of Good Planning

1. The responsibilities of all employees and the work that needs to be done are coordinated.
2. Work gets done on time.
3. Duplication of efforts by employees can be avoided.
4. Coordination between units in the organization is improved therefore improving employee relations.
5. Employees are assigned to jobs that utilize their abilities therefore improving employee morale as well as organizational efficiency.
6. Greater job control is attained.
7. Costs are minimized or reduced.
8. Employees know how their job fits into the total organization.
9. Work quality and quantity can be improved.
10. Wage costs can be reduced.
11. Equipment and materials can be ordered on time.
12. Waste can be minimized.

The Results of Improper Planning

1. Crash programs and overtime work required to complete a job.
2. Work is not completed as scheduled.
3. Employees have "nothing to do" or are not assigned to responsibilities commensurate with their abilities.
4. Machines are idle or are not optionally used.
5. Supervisors make work for employees to keep them busy - low employee morale.
6. Quarreling, bickering, buck passing by employees.
7. Duplication of work.

Plans That Fail

It is important that the reader understand that planning alone does not guarantee success. There are many unforeseeable and uncontrollable events that could jeopardize a plan or cause it to fail. Key employees could get sick, hurt or quit during a critical component of a plan. Materials, supplies, chemicals, etc. may not arrive when needed because of transportation problems. A river could go on a rampage and flood out an operation. The unforeseeable and uncontrollable events that could jeopardize the success of a plan is only limited to one's imagination.

Below is a brief list of other reasons why a plan could fail:

1. The plan itself was poor.
2. Lack of motivation by supervisor.
3. When plan was developed the operational employees were not involved.
4. The planner had a lack of knowledge of a specific task or operation.
5. The planner had overplanned - resulting in too much detail.
6. Time allotted for implementation on total plan or key components of plan was insufficient.
7. Outside pressures - political, etc.
8. Plan was too rigid.

Summary

Planning is an essential function of management for any organization. Failure to plan will result in lost time, wasted manpower, poor utilization of machinery and equipment and misuse of materials. Planning requires cooperation and coordination between management and operative employees as well as between units or departments within an organization. Requirements of a good plan must also:

1. Include imagination and creativity on the part of the planner.
2. Include provisions for uncertainty - backup alternative courses of action.

3. Have a committment on part of top management and operational employees.
4. Be continuous - daily plans must fit into weekly plans which must be compatible to monthly plans which must be compatible to long term plans.
5. Be realistic.

SELF-TEST

1. List the four basic functions of supervisory management.	planning organizing directing controlling
2. Define planning.	Looking ahead, using factual information and experience to decide on a specific course of action to achieve a desired result.
3. True or False. The person responsible for developing a plan need not consult with those who will be responsible for implementing the plan.	False

ORGANIZING

Another function of supervisory management is organizing. Organizing is the ability to appropriately schedule the organization's personnel, materials, equipment, machinery and facilities into an effective working unit. The purpose of organizing is to use the organization's resources mentioned above in the most efficient way so that organizational and/or departmental plans can be achieved.

Principles of Organizing

In order to perform the function effectively, the supervisor must clearly and fully know and understand the responsibility of his department and the abilities and needs of the employees and supervisors. For example, is the work to be performed creative or is it routine? The type of organizational structure developed for the department must meet the needs of the people and tasks to be performed. It would be frustrating for a creative person to be continually assigned tasks that are routine. At the same time, it would be equally frustrating for a person who is less creative to be assigned tasks that require a great deal of creativity. In short, are the people who are employed in the department or unit thinkers, doers, generalists, or specialists. Only when you know this can you assign the right person to the right job.

Other very important considerations for organizing your organizational unit are listed below:

1. Unity of Command is essential - one employee should have only one supervisor. No employee can perform his job effectively if he must report to more than one supervisor.
2. Delegate - assign the right employee to the right job then give them the required authority and responsibility for getting the job done.
3. Allow employees to make decisions that will help facilitate their job tasks.

DIRECTING

Directing is seeing that the right resources (people, machinery, materials, facilities, supplies) are being used on the right job and are heading in the right direction - so that the specific task(s) at hand can be achieved.

In order to perform the directing function properly, the supervisor must recognize that most if not all work situations involve a complex maze of relationship. There exists a tangled mass of people's ambitions and abilities, mechanical systems, equipment, and facilities, not to mention the problems of weather and other variables.

In short, directing is more than giving instructions. It is effectively assigning tasks according to established policy, procedures, and using techniques to optimize the output of people, material, machines, and money. In order to do this, the supervisor must be able to communicate, counsel, assign, train and motivate those who report to him.

SELF-TEST

True or False.

1. Directing is telling people what to do.	False
2. It is ok for an employee to have more than one boss.	False
3. When the supervisor is concerned with the organizing function, he does not need to worry about the plans for the treatment plant as they are not related.	False
4. Assigning the right person to the right job is part of the directing function.	True or False. It mainly fits within the Organizing Function but cannot be separated from the Directing Function.

CONTROLLING

The basic function of controlling is to establish some system by which feedback is given the supervisor. Feedback concerning how operative employees are performing; the quality and quantity of work being performed and the stage of completion of short and long term plans. Feedback can be given in oral or written reports, personal observation, or any other form of communication designed to appraise on a regular basis "how things are going on the job."

Although control can be achieved through a system of formal or informal reports and observations, the basic purpose is the same - to make sound judgements. As in any business transaction or operations an important tool for assisting the supervisor in the controlling function is to use reports and records. Both reports and records are essential for efficient plant management.

The bulk of the following information on Records and Reports has been modified from the publication "Operation of Wastewater Treatment Plants" published by the Environmental Protection Agency Office of Public Health Education.

Records

Records are needed for the following reasons:

1. To determine the cost and efficiency of the plant and its treatment units.
2. To review past problems and assist in projecting future problems and correct them before they occur.
3. To show type and frequency of maintenance of operating units.
4. To evaluate the effectiveness of existing maintenance program.
5. To provide data upon which to base recommendations for modifying plant operation and facilities.
6. To serve as a basis for the design of future treatment units.
7. To support budget requests for personnel, additional facilities, or equipment.
8. To record the necessary data concerning accidents for developing or revising a "preventive program" or to be used if needed in damage suits brought against the district or municipality. (As soon as possible after an accident, someone should record the chain of events leading to the accident, exactly what happened, and any preventive or corrective action.)
9. To record data concerning water pollution and public health aspects required by regulatory agencies.
10. To provide the actual data for the preparation of weekly, monthly, or annual reports to administrative officials, the public, and regulatory agencies.
11. To provide personnel data on individual employees.
12. To show that the final product is acceptable to the consumer.
13. To provide an alert for changing rain water equality.
14. To show that the final product meets plant performance standards.
15. To aid in answering complaints.

Records must be permanent, complete, and accurate. Write entries on data sheets in ink or with an indelible pencil. A lead pencil should never be used because notations can smudge and be altered or erased. False and misleading records may actually do more harm than lack of records. Only useful records should be kept and records no longer useful should be discarded. Of course, records of lab analysis should be kept indefinitely.

Classification of Records and Type

The type of records to be kept will depend on the size and type of plant. The specific records required will also be determined by the size and type of treatment processes of the plant. Typical data sheets are included at the end of this module - sedimentation, coagulation, filter rates and amount of chemical used for disinfection and other purposes (ie. chlorine, fluorine).

Records are generally separated into five classifications:

1. Operation and performance records
2. Descriptive and inventory records of the physical plant and stock
3. Maintenance records
4. Financial or cost records
5. Personnel

Operation Records

The minimum amount of record keeping that may be required is as follows:

1. Daily records of flows into the plant.
2. Flows into the distribution system.
3. Chemical, physical, and bacteriological characteristics of influent and effluent.
4. Amount of electrical power consumed.
5. Amount of chemicals used.
6. Unusual happenings such as floods, storms, complaints, and other significant events. Any other unusual event should be recorded if there is any possibility that a record of these events may be needed in the future, either for legal or administrative purposes. The main idea to keep in mind is to record only that data which may eventually be used.

Physical Plant and Stock Inventory

As a minimum, the following records are essential for proper evaluation of plant facilities and for making future recommended modifications or additions.

1. Contract and "as built" plans and specifications of treatment facility. This includes detailed piping and wiring of plant.

2. Plans and operating instructions for plant equipment.
3. Costs of major equipment and unit items.
4. A complete record and identification card for all major equipment. The card should include name of manufacturer and identifying code number.
5. Lists of tools, materials, chemicals, lab reagents and supplies, and office supplies.

Maintenance Records

Records should also be kept on maintenance - preventive or repair, frequency, cause of breakdown, operator making repair or maintenance check. Any information that will help prevent or project future breakdowns should be recorded.

Financial or Cost Records

Keep lists of purchases and expenses to date during fiscal year. Comparisons should be made with budget allocation to avoid excess purchases.

Personnel

Employee personnel records, including annual performance ratings, should be maintained for each of the plant employees.

Frequency of Records

Records at most treatment facilities are kept daily and on a monthly basis.

Daily Records

Data to be recorded will depend upon the type and size of the plant. Examples of specific record forms are contained at the end of this module. One of the most important daily records is a day-by-day diary or log of events and operations during the day. A daily diary or log should be maintained in every plant, and in large plants at each section (such as lab, maintenance). The log may be a spiral notebook or a standard daily diary made for that purpose.

The information entered in the plant log should be pertinent only to plant functions. Log entries should include at the top of the page the day of the week, the date, and the year. The names of the operators working at the plant, and their arrival and departure times, should also be included. Log entries should be made during the day of various activities and problems as they develop. DO NOT WAIT until the end of the day to write up the log as some items may be overlooked. If the operator will take a few minutes to make log entries in the morning and afternoon, he will develop a good log. Logs are beneficial to the operator and to people who replace the operator during vacations, illnesses, or leaves of absence. A well-kept log may prove very helpful to the operating agency as legal evidence in certain court cases.

Information to be Included

As previously discussed the extent to which record keeping should be practiced depends entirely upon their potential use. The type of treatment, the volume of water treated, and the kind and importance of installations auxiliary to the treatment plant will control the amount of necessary record keeping. As an example, the minimum daily records kept at a fairly large size treatment plant may include the following items:

1. Precipitation and weather temperatures
2. Pump usage and pressure in the various parts of the distribution system
3. pH of influent and effluent
4. Turbidity
5. Alum use (lbs)
6. Chlorine use (lbs)
7. Lime use (lbs)
8. Iron salts, all chemicals (l[illegible]
9. The amount of water being pumped into and out of the various water treatment basins
10. The physical and chemical composition of water is at the various points in the treatment and distribution system. Example: turbidity, pH, alkalinity, hardness, free and total chlorine, flourine, color, odor, taste, etc.
11. Dead ends flushed

12. Complaints received (odor, taste, color, pressure)
13. Any unusual influent characteristics such as appearance or odors.

Other basic items of information to be recorded are:

Surface Source

1. Air temperature
2. Raw water temperature
3. Rainfall data
4. Run off data
5. Height of reservoir vs. storage
6. Capacity
7. Raw water quality
8. Raw water quantity used
9. Chemical spills, oil, etc.
10. Stream flow (C.F.S.)
11. Discharges from dams above water intakes

Ground Source

1. Raw water temperature
2. Raw water quality
3. Well logs
4. Static levels
5. Pump test data
6. Pump performance curves
7. Draw down levels
8. Observation well data
9. Quantity pumped
10. Pumping intervals
11. Recovery rates

Treatment

1. Amount of water treated with chemicals
2. Chemical dosage; pound/hr., pound/day
3. Total amounts of chemical used
4. Amount of water filtered
5. Number of filters in service
6. Number of hours filters are in service
7. Final loss of head before filter was washed

8. Amount of washwater used
9. Length of time washwater was applied
10. Rate of wash
11. Cycle times for diatomaceons earth filters, pressure, sand, etc.
12. Daily or more frequent results of chemical, physical and bacteriological laboratory tests
13. Minimum, average, maximum figures for laboratory testing

Pumping Stations

1. Total amount of water pumped
2. Amount by each pump
3. Suction and discharge pressure
4. Number of hours run by each pump
5. Daily power consumption
6. Fuel consumption

Other

1. Maintenance schedules
2. Distribution system pressures
3. Master and individual meter readings
4. New valve and hydrant installations

In addition to these basic data items, each water supply system should have:

1. Hydrant and valve maps for the distribution system
2. A list of material and equipment suppliers
3. A central file of instruction manuals for treatment equipment or processes; operational guides for waste control facilities
4. A description of the basic functions of automatic control systems
5. Engineering plans and specifications for past construction
6. Names, addresses, and telephone numbers of nearby operators and personnel of the city, county, district, or regional health office
7. Copies of the watershed rules, the latest watershed inspection report, and pipe line crossing (in case of a break).
8. The procedure for adjustments necessary in case of a major fire

The above are just a few of the many data items that make up good records. Each water supply system has its own critical areas for which data are necessary.

Monthly Records

Daily recorded data are usually written on monthly data sheets. The monthly data sheet is designed to meet the reporting needs of a particular plant and should have all important data recorded that may be used later for preparation of monthly of annual reports. The monthly logs are averages on the data collected on the daily logs and contain the pertinent information that appears on the daily logs but in a summary form.

A typical monthly data sheet is also presented at the end of this module.

Evaluation of Records

Records are not useful unless they are evaluated and used as indicators of plant operation and maintenance. Records are also useful as sources for reports to management or the public.

The recorded data should enable the operator to determine operation and maintenance of the plant. The information shown by the records should also indicate the efficiency of each unit in the plant. The importance of looking at and analyzing records frequently cannot be overemphasized.

Records should not only be analyzed as a single piece of data, but any one variation should be looked upon for its relation to another source of data.

Before any meaningful interpretation can be made of any sudden variation in data, an expected range of values has to be determined for the particular treatment unit under consideration based upon expected or past performance.

For example, if average daily flows during weekdays were around two million gallons per day and suddenly a flow of 1.5 million gallons per day was recorded, this may indicate malfunctioning of metering equipment. Likewise, an increase of flow could indicate a main break and the water may not show on the surface, it may be discharging into a sewer or underground cavity.

An excellent way to facilitate review of daily records and detect sudden changes or trends is a prepared chart showing values plotted against days. Unless results are plotted, slight changes and trends can go undetected. The deviation from the expected values may have been caused by unusual circumstances or an error in observation or analysis.

REPORT WRITING

This section will discuss the major principles and mechanics of report writing, the type of report usually required of a plant operator, and a discussion of effective writing.

Importance of Reports

1. To serve as the basis of a request for additional personnel, plant addition, changes in plant operations, or an increase in budget appropriations.
2. To serve as a means to communicate to your supervisor, management, regulatory agencies, or the general public.
3. To demonstrate to your supervisor, management, regulatory agencies, and the general public that your plant is operating efficiently.

It is very important to note that no matter how efficient your plant is operating nor how well qualified and dedicated you and the other employees in the plant are, the quality of the reports submitted will have a major impression on your supervisors, management, regulatory agencies and the general public. Therefore, a poorly written report may result in an impression that the plant is not operating efficiently; or, it can result in little action or rejection of recommendation or requests.

Principles of Report Writing

Some basic principles common to good report writing are:

1. Know the purpose and objective(s) of your report.
2. Tailor your report to the person, persons or agency to whom it is directed.
3. Know your subject.
4. Organize the report to present order of ideas in a logical manner.
5. Use language in the report that will be understood by the reader.
6. Use facts and figures.
7. Be exact and brief.

Report Organization

There is no single way to organize a formal report. Therefore, you should try to organize the report in a logical sequence to present your data, findings, or tell your story. An example of a general format is presented below:

- A. Title Page - the title page should include
    - a. Report Title (should be brief, concise and clearly tell what report is about)
    - b. Who prepared the report
    - c. Who the report was prepared for
    - d. Date report was prepared
- B. A one page Summary or Abstract of report (this page should summarize the report and state:
    - a. Major purpose(s) of report
    - b. Brief statement of problem
    - c. Method(s) used to solve problem
    - d. Major findings
    - e. Major recommendations
- C. Table of Contents
- D. List of Tables and Figures
- E. Body of Report
    - a. Introduction - describing purpose of report, need for report and background information
    - b. Statement of problem(s)
    - c. Method(s) used for solving problem(s)
    - d. Data analyses - listing of past and existing data pertinent to solving problem as well as tables, figures, and mathematical computations used to assist in solving problem
    - e. Findings
    - f. Summary
    - g. Conclusions and Recommendations
    - h. Concerns and additional problems uncovered during gathering of data for preparing this report
- F. Appendix

The abstract, conclusion and recommendations sections of a report should receive the most attention and review. Therefore, is it important that these sections be stated clearly, briefly, and in a language that will be understood by your readers. It is also important to make sure that the conclusions and recommendations are supported in the body of the report.

Whether you are writing a report as described above or sending a memorandum to a supervisor be sure to check for organization and content as follows:

1. Is the material presented in an organized way?
2. Is there duplication?
3. Is there omission of an important item?
4. Is the material presented really necessary to make your point and support your conclusions or recommendations?

Unnecessary material, duplication of information, or an omission of materials will only serve to weaken your case by confusing the reader or clouding the main issues.

HINT: Obtain previously written reports from your supervisor, fellow employees or other water treatment plant operators to help you. These reports can be used as a guide for your report. Adapt the format of those reports to meet the procedures or needs of your plant. Improve upon the report when possible. Always keep an extra copy of your reports for future reference. You will only receive help and assistance when you ask for it and by asking you are only showing that you are concerned and want to do a good job.

Don't wait until the last minute to begin preparing a report. As soon as you are notified or aware that a report is needed, begin gathering the necessary information from your records etc. and begin adapting it into report format.

Types of Reports

There are many types of reports ranging from memorandum to an annual report to management.

Reports may be (1) a monthly plant operation reports, (2) a report to a regulatory agency, such as a health department, or (3) a quarterly or annual report to management or the public.

Monthly Reports

The monthly reports are used in the preparation of the annual report. Preparation of the monthly report consists of the following preliminary activities:

1. Gathering daily records
2. Reviewing daily log sheets for any significant or unusual events during the month.
3. Jotting down ideas that need to be included in the narrative section of the report

In small plants, a monthly report may consist mainly of data sheets giving the pertinent facts on:

1. Laboratory analysis and effectiveness of plant treatment and its various units
2. Cost data on labor, chemicals, and maintenance
3. Maintenance records
4. Remarks stating unusual significant events during the month
5. Conclusions and recommendations

In some larger plants a monthly report may be required in addition to the monthly data sheets.

The monthly report is a brief summary of combined information from the monthly data sheets and daily logs. The report is put together in outline form with a dozen or so subheadings required for a secondary plant. The reports are useful to the operator and his supervisor to keep them informed of plant functions and problem areas.

The subheadings may be labeled as to flow pattern through the plant and generally describe in narrative form the physical characteristics, maintenance and operation problems, and unusual events during the month.

MONTHLY REPORT

A. Flow
   1. Total amount of flow passed through the plant for month
   2. Maximum daily flow
   3. Minimum daily flow
   4. Average daily flow
   5. Flow meter problems

B. Headworks
   1. Raw water screening: operations and maintenance problems
   2. Unusual material in the raw water, such as oil, silt, odors

C. Primary clarifiers
   1. Operation or maintenance problems
   2. Sludge pumped, solids concentration
   3. Effluent characteristics

D. Filtration System
   1. Amount of water filtered, average
   2. Amount of wash water used, average
   3. Record of maintenance and problems encountered

E. Secondary clarifiers
   1. Operation or maintenance
   2. Sludge pumped, solids concentration

F. Chlorination
   1. Pounds of chlorine used/month
   2. Pounds of chlorine used/day, average
   3. Chlorine residuals
   4. Chlorinator problems

G. Water pumps
   1. Problems and maintenance

H. General
   1. Power failures
   2. Accidents
   3. Visitors
   4. Grounds and building maintenance
   5. Plant cost
      a. Man-hours worked
      b. Equipment parts
      c. Power and fuel
      d. **All chemicals**, received, used, in storage
      e. Miscellaneous
   6. Complaints, type, cause, what was done about them
   7. Laboratory, chemical results

Annual Reports

The annual report receives wider distribution and is the report more likely to be reviewed by the public, management, and other governmental agencies.

The annual report is, in part, a compilation of data obtained in the monthly reports. It summarizes the plant's yearly efficiency, cost data, and analysis of plant operation costs, and contains recommendations for next year's operations.

In addition, an annual report should contain a short introduction to provide a background to the reader, giving a brief history and reason for the report.

The body of the report should contain schematic drawings, pictures, and other attractive graphs whenever possible, and should include at least the following items:

a. A letter of transmittal

b. Conclusions and recommendations

c. A brief description and schematic diagram of the system

d. An organization chart showing the various functional divisions and their chiefs

e. A statistical summary of general plant data such as:
   1. Population served
   2. Water flows (maximum, average, minimum)
   3. Plant unit data, percent removal and efficiency of various units

f. Body of report which includes a brief description and supporting tables, graphs, or charts needed to back up final recommended actions or requests on such topics as:
   1. Water quality
   2. Chemicals, amount used, etc.
   3. Screening
   4. Pumping
   5. Raw water quality (maps--summary data)
   6. Maintenance and repair
   7. Financial data such as assets, liabilities, revenue

g. Appendix which includes summary data by month for the annual report year, giving minimum, maximum, and average values for:
   1. General plant data
   2. Treatment unit data
   3. Loadings and efficiency of treatment
   4. Chemical, physical, and bacteriological data on influent and effluent
   5. Chemical, physical, and bacteriological data on water pumped into the distribution system

Report writing, especially for an operator not experienced in report writing, can seem like a formidable task. But with provided quidelines, a review of effective writing, and some real effort, anyone who can read can produce an effective report.

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DAILY LOG

WATER PLANT PUMPAGE

DAILY LOG Water Plant Pumpage

Date August 27, 1978

Time	Power	Lake Pumps									Main Pressure	Man. Pres PSI
		No. 1			No. 2			No. 3				
		on	off	time	on	off	time	on	off	time		
12 M	—	✓		—				✓		—	66	7.0
1:00 am	/			/						/	66	7.0
2:00	/			/						/	65	7.0
3:00	/			/						/	64	7.2
4:00	/			/						/	66	7.0
5:00	/			/						/	44	7.0
6:00	/			/						/	44	7.6
7:00	/			/						/	65	7.6
8:00	/			/						/	64	5.3
9:00	/			/						/	62	7.6
10:00	/			/						/	60	7.6
11:00	/			/						/	62	7.6
12 N	/			/						/	62	7.6
1:00 pm	/			/						/	62	7.6
2:00	/			/						/	63	7.6
3:00	/			/						/	63	7.6
4:00	/			/						/	62	7.6
5:00	/			/						/	61	7.6
6:00	/			/						/	62	7.6
7:00	/			/						/	62	7.2
8:00	/			/						/	63	7.2
9:00	/								✓	/	64	7.2
10:00	/									—	64	7.2
11:00										—	66	7.6
12 M				/						—	66	7.6
Total	24			24						21		

Time	Raw Pumps						Air Compressor					
	No. 1			No. 2			No. 1			No. 2		
	on	off	time	on	off	time	on	off	time	on	off	time
12 M				✓		—	✓		—			
1:00 am						/			/			
2:00						/			/			
3:00						/			/			
4:00						/			/			
5:00						/			/			
6:00						/			/			
7:00						/			/			
8:00						/			/			
9:00						/			/			
10:00						/			/			
11:00						/			/			
12 N						/			/			
1:00 pm						/			/			
2:00						/			/			
3:00						/			/			
4:00						/			/			
5:00						/			/			
6:00						/			/			
7:00						/			/			
8:00						/			/			
9:00						/			/			
10:00						/			/			
11:00						/			/			
12 M						/			/			
Total						24			24			

Time	Transfer Pumps						High Service Pumps								
	No. 1			No. 2			No. 1			No. 2			No. 3		
	on	off	time	on	off	time	on	off	time	on	off	time	on	off	time
12 M	✓		—	✓		—				✓		—			
1:00 am			/			/						/			
2:00			/			/						/			
3:00			/			/						/			
4:00			/			/					✓	/			
5:00			/			/						—			
6:00			/			/				✓		—			
7:00			/		✓	/						/			
8:00			/	✓		—						/			
9:00			/			/						/			
10:00			/			/						/			
11:00			/			/						/			
12 N			/			/						/			
1:00 pm			/			/						/			
2:00			/			/						/			
3:00			/			/						/			
4:00			/			/						/			
5:00			/			/						/			
6:00			/			/						/			
7:00			/			/						/			
8:00			/			/						/			
9:00			/			/						/			
10:00			/			/						/			
11:00			/			/						/			
12 M			/			/						/			
Total			24			22						22			

Remarks

Plant On ____________

Plant Off ____________

Hours of Operation 24

SAMPLE COPY

Operator

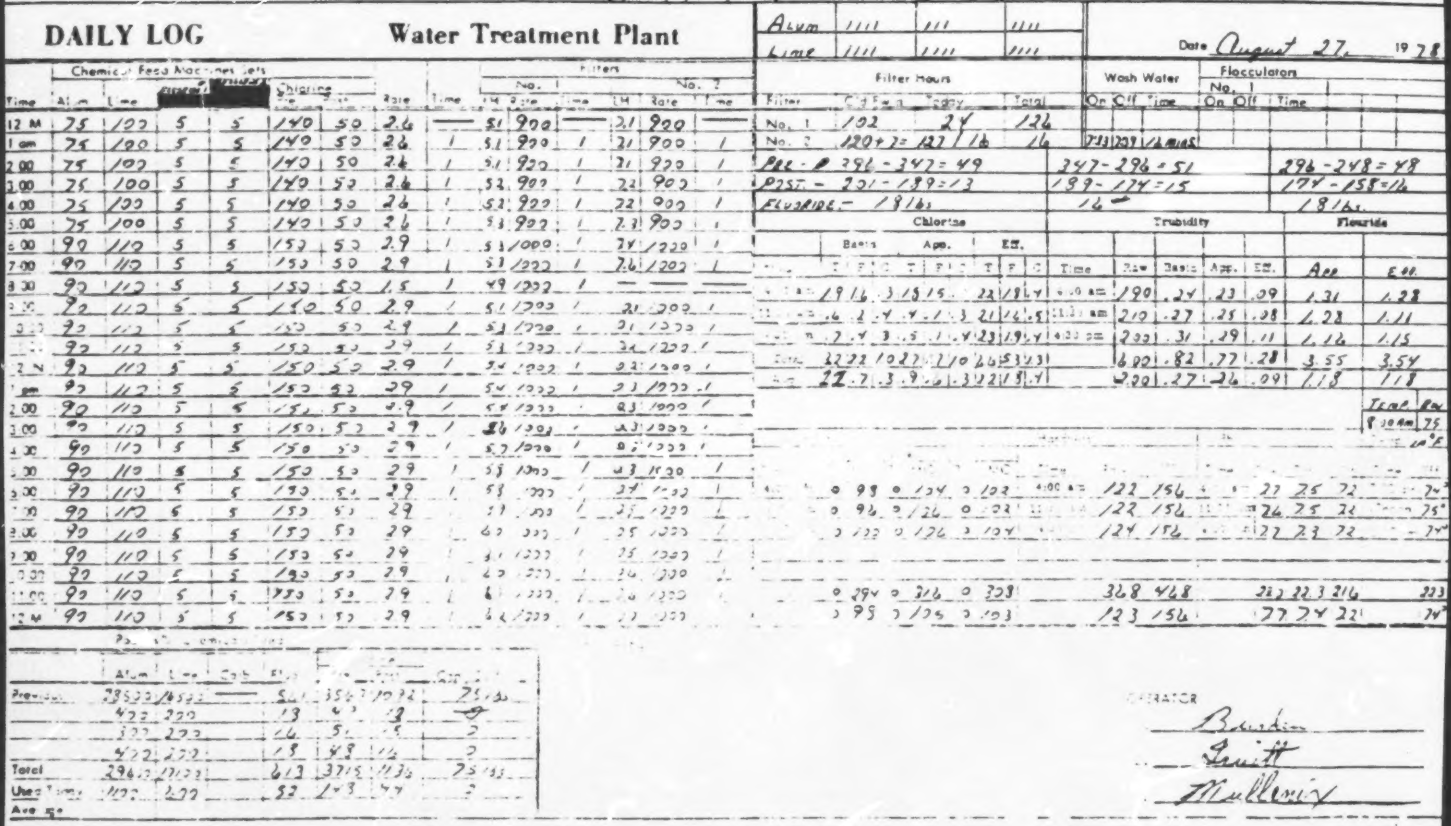
1. Purdin

It is highly recommended that a Daily Log should show KW Hrs.

DAILY LOG

WATER TREATMENT PLANT

SAMPLE COPY



DAILY LOG **Water Treatment Plant**

Alum	1111	111	1111	
Lime	1111	1111	1111	Date August 27, 1978

	Chemical Feed Machines Sets				Chlorine				Filters					
									No. 1			No. 2		
Time	Alum	Lime	[redacted]	[redacted]	Pre	Post	Rate	Time	LH	Rate	Time	LH	Rate	Time
12 M	75	100	5	5	140	50	2.6	—	51	900	—	21	900	—
1 am	75	100	5	5	140	50	26	1	51	900	1	21	900	1
2.00	75	100	5	5	140	50	2.6	1	51	900	1	21	900	1
3.00	75	100	5	5	140	50	2.6	1	52	900	1	22	900	1
4.00	75	100	5	5	140	50	26	1	52	900	1	22	900	1
5.00	75	100	5	5	140	50	26	1	53	900	1	23	900	1
6.00	90	110	5	5	150	50	2.9	1	53	1000	1	24	1000	1
7.00	90	110	5	5	150	50	2.9	1	53	1000	1	26	1000	1
8.00	90	110	5	5	150	50	1.5	1	49	1000	1	—	—	—
9.00	90	110	5	5	150	50	2.9	1	51	1000	1	21	1000	1
10.00	90	110	5	5	150	50	2.9	1	52	1000	1	21	1000	1
11.00	90	110	5	5	150	50	2.9	1	53	1000	1	22	1000	1
12 N	90	110	5	5	150	50	2.9	1	54	1000	1	22	1000	1
1 pm	90	110	5	5	150	50	29	1	54	1000	1	23	1000	1
2.00	90	110	5	5	150	50	2.9	1	54	1000	1	23	1000	1
3.00	90	110	5	5	150	50	29	1	56	1000	1	23	1000	1
4.00	90	110	5	5	150	50	29	1	57	1000	1	23	1000	1
5.00	90	110	5	5	150	50	29	1	58	1000	1	23	1000	1
6.00	90	110	5	5	150	50	29	1	58	1000	1	24	1000	1
7.00	90	110	5	5	150	50	29	[illegible]	59	1000	1	25	1000	1
8.00	90	110	5	5	150	50	29	1	60	1000	1	25	1000	1
9.00	90	110	5	5	150	50	29	1	61	1000	1	25	1000	1
10.00	90	110	5	5	150	50	29	1	62	1000	1	26	1000	1
11.00	90	110	5	5	150	50	29	1	[illegible]	1000	1	26	1000	[illegible]
12 M	90	110	5	5	150	50	2.9	1	[illegible]	1000	1	[illegible]	1000	

Filter Hours				Wash Water			Flocculators No. 1		
Filter	Old Run	Today	Total	On	Off	Time	On	Off	Time
No. 1	102	24	126						
No. 2	120+7= 127	16	16	7:33	7:39	6 mins			

PRE - Ø 296 - 347 = 49	347 - 296 = 51	296 - 248 = 48
POST - 201 - 189 = 13	189 - 174 = 15	174 - 158 = 16
FLUORIDE - 18 lbs	16	18 lbs.

Chlorine										Turbidity					Flouride	
	Basin			App.			Eff.									
Time	T	F	C	T	F	C	T	F	C	Time	Raw	Basin	App.	Eff.	App	Eff.
6:00 am	19	16	.3	18	15		22	18	.4	6:00 am	190	.24	.23	.09	1.31	1.28
11:00 am	.6	.2	.4	.4	.1	.3	21	16	.5	11:00 am	210	.27	.25	.08	1.28	1.11
4:00 pm	.7	.4	.3	.5	.1	.4	23	19	.4	4:00 pm	200	.31	.29	.11	1.16	1.15
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	66	53	1.3		600	.82	.77	.28	3.55	3.54
Avg.	22	.7	.3	.9	.6	.3	22	18	.4		200	.27	.26	.09	1.18	1.18

Temp.	Raw
8:30 am	75
[illegible]	60°F

[illegible]	0	98	0	124	0	102	4:00 am	122	156	4:00 am	22	25	22	74°
[illegible]	0	96	0	126	0	103	11:00 am	122	156	11:00 am	26	25	22	Noon 75°
[illegible]	0	100	0	126	0	104	[illegible]	124	156	[illegible]	22	23	22	74°
	0	294	0	376	0	309		368	468		222	22.3	216	223
	0	98	0	125	0	103		123	156		22	24	22	74°

Purchased Chemicals

	Alum	Lime	Carb	Fluo	Chlorine Pre	Post	Car
Previous	23500	16500	—	541	3567	1092	75
	400	200		13	49	13	0
	300	200		26	51	15	0
	400	200		18	48	16	0
Total	29600	17100		613	3715	1136	75
Used Today	1100	600		53	148	44	0
Ave 5°							

OPERATOR

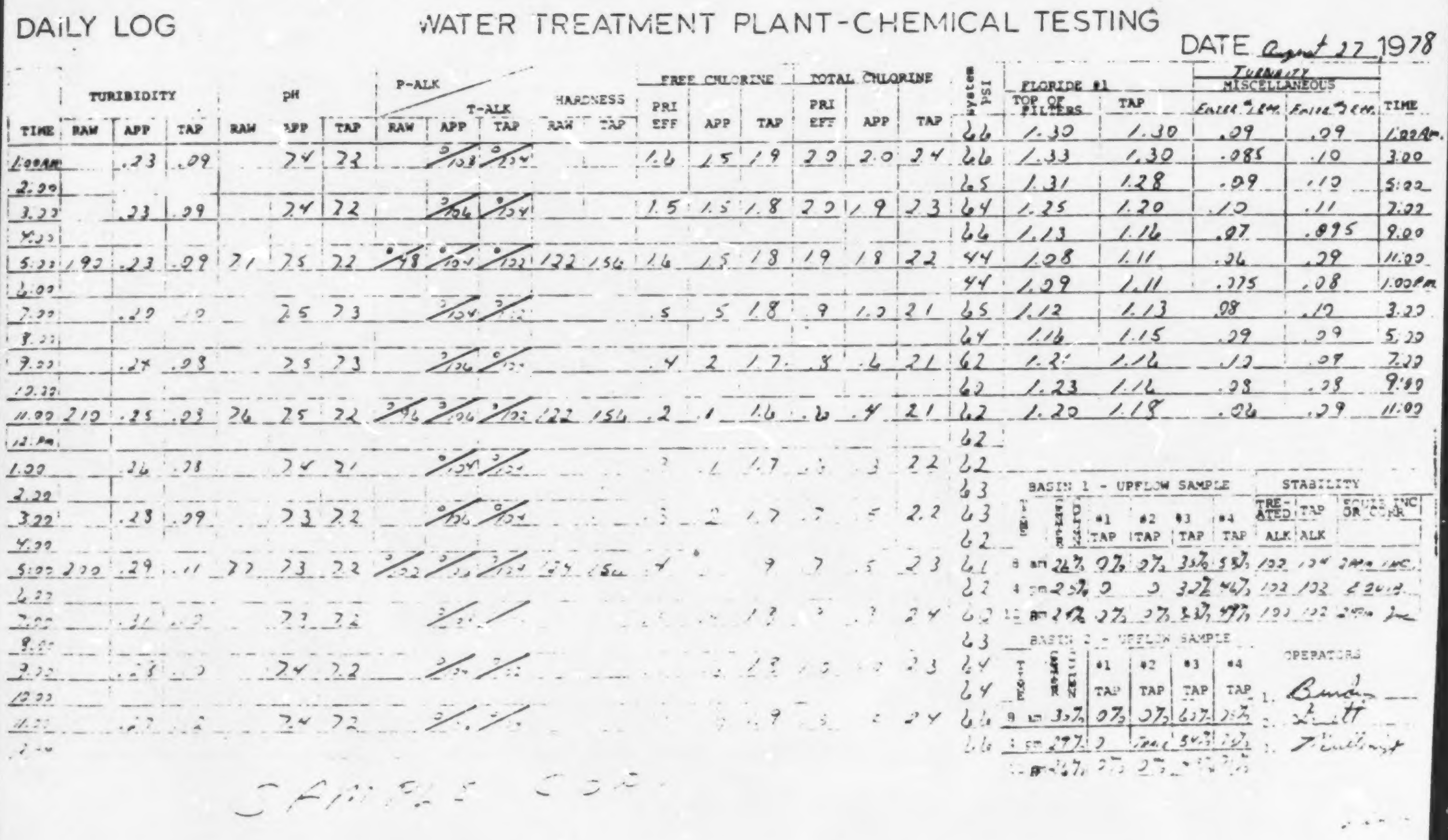
Burkin

Pruitt

Mullenix

DAILY LOG

WATER TREATMENT PLANT - CHEMICAL TESTING



DAILY LOG WATER TREATMENT PLANT-CHEMICAL TESTING

DATE August 27 1978

	TURIBIDITY			pH			P-ALK / T-ALK			HARDNESS		FREE CHLORINE			TOTAL CHLORINE		
TIME	RAW	APP	TAP	RAW	APP	TAP	RAW	APP	TAP	RAW	TAP	PRI EFF	APP	TAP	PRI EFF	APP	TAP
1:00AM		.23	.09		74	72		0/103	0/104			1.6	1.5	1.9	20	2.0	24
2.00																	
3.00		.23	.09		74	72		0/106	0/104			1.5	1.5	1.8	20	1.9	23
4.00																	
5.00	190	.23	.09	71	75	72	0/48	0/104	0/102	122	156	1.6	1.5	18	19	18	22
6.00																	
7.00		.20	.10		75	73		0/104	0/[illegible]			.5	.5	1.8	.9	1.0	21
8.00																	
9.00		.24	.08		75	73		0/106	0/[illegible]			.4	2	1.7	.8	.6	21
10.00																	
11.00	210	.25	.08	76	75	72	0/96	0/106	0/102	122	156	.2	.1	1.6	.6	.4	21
12. PM																	
1.00		.26	.08		74	71		0/104	0/[illegible]			[illegible]	.1	1.7	[illegible]	.3	22
2.00																	
3.00		.23	.09		73	72		0/106	0/104			.3	.2	1.7	.7	.5	2.2
4.00																	
5:00	220	.29	.11	77	73	72	0/102	0/[illegible]	0/104	124	156	.4	[illegible]	.9	.7	.5	23
6.00																	
7.00		.31	[illegible]		73	72		0/[illegible]	[illegible]			[illegible]	[illegible]	1.3	[illegible]	[illegible]	24
8.00																	
9.00		.28	[illegible]		74	72		0/[illegible]	0/[illegible]			[illegible]	[illegible]	1.3	[illegible]	[illegible]	23
10.00																	
11.00		.27	[illegible]		74	72		0/[illegible]	0/[illegible]			[illegible]	[illegible]	1.9	[illegible]	[illegible]	24
[illegible]																	

System PSI	FLORIDE #1 TOP OF FILTERS	FLORIDE #1 TAP	TURBIDITY MISCELLANEOUS Enter #2 Cen.	TURBIDITY MISCELLANEOUS Enter #3 Cen.	TIME
66	1.30	1.30	.09	.09	1:00AM.
66	1.33	1.30	.085	.10	3:00
65	1.31	1.28	.09	.10	5:00
64	1.25	1.20	.10	.11	7:00
66	1.13	1.16	.07	.095	9.00
44	1.08	1.11	.06	.09	11:00
44	1.09	1.11	.075	.08	1.00PM
65	1.12	1.13	.08	.10	3.00
64	1.16	1.15	.09	.09	5.00
62	1.2[illegible]	1.16	.10	.09	7.00
62	1.23	1.16	.08	.08	9:00
62	1.20	1.18	.06	.09	11:00
62					
62					
63					
63					
62					
61					
62					
62					
63					
64					
64					
66					
66					

BASIN 1 - UPFLOW SAMPLE

TIME	ENTER	OUTLET	#1 TAP	#2 TAP	#3 TAP	#4 TAP	STABILITY TREATED ALK	STABILITY TAP ALK	SCALE INC OR CORR
8 am	26%		0%	0%	35%	58%	102	104	2ppm inc.
4 pm	25%		0	0	32%	46%	102	102	2 ppm [illegible]
12 am	21%		0%	0%	33%	49%	100	102	2ppm [illegible]

BASIN 2 - UPFLOW SAMPLE

TIME	ENTER	OUTLET	#1 TAP	#2 TAP	#3 TAP	#4 TAP
9 am	32%		0%	0%	63%	75%
3 pm	27%		0	Trace	54%	73%
12 am	26%		0%	0%	[illegible]	[illegible]

OPERATORS

1.
2.
3.

SAMPLE COPY

DAILY LOG

OPERATIONS OF WATER TREATMENT PLANT

DAILY LOG — Operations of Water Treatment Plant Date August 27 19 28

Time	Filtered Meter Read	Filtered Water Gallons	High Service Read	High Service Gallons	Clear Well Feet	Clear - W in Gallons	Gain or Loss in Clear - W	Wash Water	Elev. Tow. Feet	Tower in Gallons	Gain or Loss in Elev. Tow.	Total in Storage	Gain or Loss in Storage	To Distri. System	Sold at Plant
Previous		432	1360000	—	30	1125000	—		28	1732806	—	2857806	—	—	
1 a.m.		432	1410000	150000	30	1125000	0		29	1788403	+55597	2913403	+55597	94403	
2.00		432	1550000	140000	29	1087500	-37500		30	1844000	+55597	2931500	+18097	84403	
3.00		432	1700000	150000	29	1087500	0		32	1955194	+111194	3042694	+111194	38806	
4.00		432	1850000	150000	28	1050000	-37500		34	2066388	+111194	3116388	+73694	38806	
5.00		432	1850000	0	31	1162500	+112500		34	2066388	0	3228888	+112500	0	
6.00		432	1850000	0	34	1275000	+112500		33	2010791	-55597	3285791	+56903	55597	
7.00		432	2010000	160000	33	1237500	-37500		32	1955194	-55597	3192694	-93097	215597	
8.00		432	2160000	150000	30	1125000	-112500	112500	31	1899597	-55597	3024597	-168097	225597	
9.00		432	2300000	140000	30	1125000	0		30	1844000	-55597	2969000	-55597	195597	
10.00		432	2450000	150000	30	1125000	0		30	1844000	0	2969000	0	150000	
11.00		432	2590000	140000	30	1125000	0		29	1788403	-55597	2913403	-55597	195597	
12 N		432	2740000	150000	30	1125000	0		29	1788403	0	2913403	0	150000	$97.53
1 p.m.		432	2890000	150000	30	1125000	0		28	1732806	-55597	2857806	-55597	205597	
2.00		432	3030000	140000	30	1125000	0		27	1677209	-55597	2802209	-55597	195597	
3.00		432	3180000	150000	29	1087500	-37500		27	1677209	0	2764709	-37500	150000	
4.00		432	3320000	140000	29	1087500	0		27	1677209	0	2764709	0	140000	
5.00		432	3470000	150000	29	1087500	0		27	1677209	0	2764709	0	150000	
6.00		432	3610000	140000	29	1087500	0		26	1621612	-55597	2709112	-55597	195597	
7.00		432	3750000	140000	29	1087500	0		26	1621612	0	2709112	0	[illegible]	
8.00		432	[illegible]	150000	29	1087500	0		26	[illegible]	0	[illegible]	0	[illegible]	
9.00		432	[illegible]	150000	29	1087500	0		[illegible]	[illegible]	0	[illegible]	0	[illegible]	
10.00		432	[illegible]	140000	28	1050000	[illegible]		[illegible]	[illegible]	0	[illegible]	[illegible]	[illegible]	
11.00		432	[illegible]	150000	28	1050000	0		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
12 Mid		432	[illegible]	140000	28	1050000	0		27	[illegible]	0	[illegible]	0	[illegible]	
Previous		432	1360000		30	1125000			28	1732806		2857806			
Close		432	[illegible]		28	[illegible]			[illegible]	[illegible]		[illegible]			
Total			3[illegible]		-2	-75000		[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	

Remarks:

SAMPLE COPY

PUBLIC WORKS DEPARTMENT

TIME SHEET

DATE:

	SHIFT							
NAME:	1	2	3	OT	SL	V	H	TOTAL

WATER TREATMENT
DEPARTMENT

SUPERVISOR

MONTHLY LOG

OPERATIONS OF WATER TREATMENT PLANT

43299060000

MONTHLY LOG of Operations of Water Treatment Plant

Month of August 19 38

Day	Filtered	System	Min Storage	Sold Plant	Wash Water	Used Plant	Chl.-Eff. T	Chl.-Eff. F	Chl.-Eff. C	Turbidity Raw	Turbidity App	Turbidity eff	Floride Basin	Floride [illegible]	Floride [illegible]	Penol Raw	Penol eff	M. O. Raw	M. O. eff	Hardness Raw	Hardness eff	Ph Raw	Ph eff	Lbs of Chemicals Alum	Lbs of Chemicals Lime	Lbs of Chemicals Carb	Lbs of Chemicals Flou	Chlorine Pre	Chlorine Post	Noon Temp
1		[illegible]	2502209				[illegible]	0.7	0.3	2.34	.56	.16		.84	.48	0	0	94	94	121	152	8.1	7.5	1050	550		28	109	50	72°
2		2740000	2894000				1.7	1.2	0.5	1.90	.31	.16		.80	.74	0	0	92	93	121	150	8.1	7.5	1400	550		40	149	45	72°
3		2520000	2837097	743.00			1.7	1.4	0.3	2.00	.33	.19		.84	.83	0	0	92	92	120	153	8.0	7.4	1400	550		—	148	40	72°
4		2400000	2744000		150000		2.2	1.7	0.5	2.04	.42	.24		.77	.77	0	0	94	91	120	149	8.0	7.6	1000	550		40	151	[illegible]	72°
5		2370000	2817694				2.2	1.6	0.4	1.59	.34	.21		.76	.88	0	0	93	90	122	151	7.9	7.4	[illegible]	550		—	148	47	71°
6		2460000	2572694				2.3	1.6	0.3	2.23	.26	.27		.67	.72	0	0	92	90	[illegible]	[illegible]	6.9	7.3	900	500		-	147	41	71°
7		[illegible]	[illegible]				2.0	1.6	0.5	1.76	.36	.30		.76	.71	0	0	92	92	120	151	7.8	7.2	900	500		28	142	47	71°
8		2480000	2676566		75000		2.3	1.8	0.4	1.57	.35	.30		.81	.76	0	0	95	92	121	150	7.8	7.3	900	500		—	148	54	72°
9		2850000	2727207		75000		2.3	1.7	0.5	1.66	.38	.22		.71	.70	0	0	94	91	122	[illegible]	7.6	7.2	900	550		28	142	47	72°
10		2680000	2894200				1.9	1.5	0.4	1.84	.40	.14		.86	.86	0	0	93	90	120	146	7.8	7.3	900	550		—	147	47	72°
11		[illegible]	[illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	.20		[illegible]	[illegible]	0	0	92	87	121	150	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	40	72°
12		2460000	2725903				2.5	1.9	0.6	1.61	.25	.14		.71	.80	0	0	92	93	121	151	7.8	7.5	800	550		—	130	38	72°
13		2390000	2762097		75000		2.7	1.7	0.7	1.70	.30	.16		1.02	.78	0	0	90	92	121	150	7.8	7.4	930	500		34	150	38	72°
14		2590000	2749306		75000		2.4	1.9	0.5	1.73	.31	.14		.89	.92	0	0	90	90	120	152	7.7	7.5	900	550		38	150	37	73°
15		2550000	2763403				2.5	2.3	0.5	1.76	.27	.11		.64	.72	0	0	94	94	121	152	7.7	7.3	900	500		—	174	37	74°
16		2410000	2412706				2.1	1.6	0.4	2.00	.34	.10		.89	.75	0	0	94	94	121	152	7.8	7.3	900	550		41	146	38	74°
17		2500000	3006500				2.6	1.9	0.7	1.93	.34	.10		1.05	.87	0	0	96	96	122	150	7.7	7.3	900	500		104	146	37	73°
18		[illegible]	[illegible]		75000		2.7	2.0	0.7	2.42	.27	.12		1.10	1.19	0	0	76	94	122	147	7.3	7.2	1000	500		23.75	146	32	73°
19		2170000	3241388		75000		2.7	2.1	0.6	1.86	.53	.11		1.35	1.37	0	0	95	92	122	149	7.7	7.4	900	600		21.25	137	35	73°
20		2530000	2928888				3.0	2.5	0.5	1.67	.43	.10		1.56	1.26	0	0	95	95	122	150	7.7	7.3	900	600		33	133	38	74°
21		2410000	2670306	167.00			2.6	1.9	0.7	1.78	.21	.10		1.15	1.37	0	0	95	93	122	153	7.7	7.5	900	550		6	126	37	74°
22		2670000	2503515																					900	650		47	127	37	74°
23		2790000	2336724		75000																			1100	600		0	128	38	74°
24	3740000	4030000	2336724		75000		1.7	1.3	0.4	1.88	1.18	.24		1.21	1.13	0	0	97	96	122	148	7.7	7.3	1000	700		48	130	35	74°
25		2990000	2447918				1.9	1.5	0.4	2.56	0.74	.20		.92	.99	0	0	99	99	123	150	7.7	7.3	1100	850		41	127	37	73°
26		2760000	2377209		75000		1.7	1.2	0.4	1.91	.23	.30		.90	.76	0	0	101	102	122	150	7.7	7.3	1100	750		44	125	36	73°
27		2690000	2670306		75000		2.0	1.6	0.5	2.18	1.31	.41		1.01	.96	0	0	100	104	122	152	7.7	7.2	900	650		24	127	37	73°
28		2340000	2745306				2.7	1.6	0.2	211	109	28		82	85	0	0	96	89	122	151	7.7	7.2	500	650		41	127	38	74°
29		2110000	2707806	152.75			2.7	1.6	0.7	196	125	63		95	94	0	0	94	94	122	152	7.8	7.2	1000	650		24	131	35	73°
30		[illegible]	[illegible]		[illegible]		2.3	1.2	[illegible]	[illegible]	1.18	.92		77	90	0	0	95	95	124	154	7.8	7.1	1000	600		—	130	38	74°
31		[illegible]	2563519				2.0	1.5	0.5	1.72	0.94	.22		.59	.77	0	0	97	100	123	153	7.8	7.1	900	600		44	111	37	73°
Total		81,100,000		821.00	1,050,000																			[illegible]	[illegible]		[illegible]	[illegible]	[illegible]	

Remarks

Also should include a column for % of Wash Water.

MONTHLY PUMPAGE

OF TREATMENT PLANT

MONTHLY PUMPAGE of Treatment Plant

Month of August 19[illegible]

Date	Power	Lake Pump			Raw Pumps		Air Comp		Transfer		High Service			Plt Oper.	Total Lake			Air Comp		Transfer		High Service			Total Pl.	Total Power
		No 1	No 2	No 3	No 1	No 2	No 1	No 2	No 1	No 2	No 1	No 2	No 3		No 1	No 2	No 3	No 1	No 2	No 1	No 2	No 1	No 2	No 3		
1	24	24		11		24	24		24	24		21		24	24		11	24		24	24		21		24	24
2	24	24		24		24	24		24	24		22		24	48		35	48		48	48		43		48	48
3	24	24		10		24	24		24	24		20		24	72		45	72		72	72		63		72	72
4	24	24				24	24		23	23	18	1		24	96			96		95	95	18	64		96	96
5	24	24				24	24		24	24	19			24	120			120		119	119	37			120	120
6	24	24		4		24	24		24	24	20			24	144		49	144		143	143	57			144	144
7	24	24		20		24	24		24	24	19			24	168		69	168		167	167	76			168	168
8	24	24		12		24	24		24	24	21			24	192		81	192		191	191	97			192	192
9	24	24		15		24	24		24	23	22			24	216		96	216		215	214	119			216	216
10	24	24		24		24	24		24	24	21			24	240		120	240		239	238	140			240	240
11																										
12	24	24		13		24	24		24	24	20			24	288		157	288		287	286	181			288	288
13	24	24				24	24		23	24	19			24	302		157	312		310	310	200			312	312
14	24	23		10		24	24		24	23	20			24	322		167	336		334	333	220			336	336
15	24	24		24		24	24		24	24	19			24	346		191	360		358	357	239			360	360
16	24	24		24		24	24		24	24	22			24	370		215	384		382	381	261			384	384
17	24	24		10		24	24		24	24	22			24	394		225	405		406	405	283			405	405
18	24	23		15		24	24		23	24	20			24	417		240	432		429	429	303			432	432
19	24	24		7		24	24		24	23	19			24	441		247	456		453	452	322			456	456
20	24	24		[illegible]		24	24		24	24	21			24	465		247	480		477	476	343			480	480
21	24	24		8		24	24		24	24	19			24	489		255	504		501	500	362			504	504
22	24	24		14		24	24		24	24	21			24	513		269	528		525	524	383			528	528
23	24	24		7		24	24		23	24	22			24	537		276	552		548	548	405			552	552
24	24	24		24		24	24		24	23	24			24	561		300	576		572	571	429			576	576
25	24	24		21		24	24		24	24	24			24	585		321	600		596	595	453			600	600
26	24	24		16		24	24		23	24	24			24	609		337	624		619	619	477			624	624
27	24	24		24		24	24		24	23	22			24	633		361	648		643	642	499			648	648
28	24	24		10		24	24		24	24	23			[illegible]	[illegible]		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]	672
29	24	24		2		24	24		24	24	22			[illegible]	681		[illegible]	[illegible]		[illegible]	[illegible]	[illegible]			[illegible]	[illegible]
30	24	24		14		24	24		23	24	21			24	705		[illegible]	[illegible]		[illegible]	713	565			720	720
31	24	24		10		24	24		24	24	22			24	729		397	744		738	[illegible]	587			744	744
Total															729		397	744		738	737	587	64		744	744

SUGGESTED READINGS

If you wish to find further information in the topics discussed in this module, the following books are recommended:

1. Basic Water Treatment Operator's Manual, 1971 M18, AWWA, New York, NY.
2. Water Utility Management, 1959, M5, AWWA, Denver, CO.
3. Terry, George R. "Supervision", Richard D. Irwin, Inc. Homewood, IL, 1978.
4. Souther, J.W., "Technical Report Writing", John Wiley & Sons, Inc., New York, 1957.
5. Operation of Wastewater Treatment Plants, California Water Pollution Control Association, Environmental Protection Agency, Sacramento, CA Chapter 17.
6. Manual of Instruction for Water Treatment Plant Operators, New York State Department of Health, Office of Public Health Education, Albany, NY Chapter 18.

POST-EVALUATION (6 pts. each)

1. Why should unusual happenings be recorded and described?
2. Why should records frequently be reviewed and analyzed?
3. What is the purpose of monthly and annual reports.
4. List the four basic functions of supervisory management.
5. Define planning.

True or False (2 pts. each)

1. The person responsible for developing a plan need not consult with those who will be responsible for implementing the plan.
2. Directing is telling people what to do.
3. It is ok for an employee to have more than one boss.
4. When the supervisor is concerned with the organizing function he does not need to worry about the plans for the treatment plant as they are not related.
5. Assigning the right person to the right job is part of the directing function.
6. Most of the primary supervisory functions are conducted relatively infrequently by plant supervisors.
7. Planning means assigning tasks to the right people.
8. A standing policy may be though of as a plan, just as a schedule may be thought of as a plan.
9. Organizing involves developing a systematic method for predicting future events.
10. Reports and control are synonymous terms.
11. Control means taking corrective action.
12. Reports, ideally, should reflect either the most optimistic, or the most pessimistic view of the area covered.

Fill-In (10 pts.)

1. Explain the importance and need for records.

Multiple Choice - Note: Some questions may have more than one answer, 1 point for each correct answer.

1. Well-written plant reports are important because they:
    1. look nice
    2. Communicate to management the accomplishments of you and your plant
    3. Can serve to justify a plant budget
    4. Keep the operator from maintaining his equipment
    5. Explain to the public the operation and function of your plant

2. Plant records are important because they:
    1. Provide essential information when a plant is modified or expanded
    2. Show type and frequency of maintenance of operating units
    3. Make pleasant music
    4. Fill up storage space so the public won't think there is any wasted space around the plant
    5. Provide data required by regulatory agencies
3. What types of records should be kept by an operator?
    1. Operation
    2. Inventory
    3. Complaints
    4. Music
    5. Maintenance
4. Which of the following entries should be made in the plant log?
    1. Jones won the football pool.
    2. Smith cleaned clarifier weirs today.
    3. Switched chlorine feed from No. 2 cylinder to No. 1
    4. Heavy thunderstorm hit north end of town around 3 PM and lasted for approximately 15 minutes.
    5. Mayor Charles visited plant and discussed some recent odor complaints by plant neighbors.
5. Records are not useful unless they are:
    1. Evaluated
    2. Used to fill bookcases
    3. Used to prop up slide projectors
    4. Used as indicators of plant operation and maintenance
    5. Burned for heat
6. A poorly prepared report may:
    1. Prevent the operator from getting a pay raise
    2. Indicate to management that the operator doesn't know what he is doing
    3. Indicate to the regulatory agency that the plant is not operating efficiently
    4. Convince the public that they shouldn't spend any more money on the plant
    5. Indicate that the operator doesn't care about his job
7. Some of the basic principles of good report writing include:
    1. A college degree
    2. Knowledge of the subject
    3. A good typewriter
    4. Organizing the report to present ideas in a logical fashion
    5. Using facts and figures

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8. Effective writing means:
   1. Use of correct grammar
   2. Elimination of needless words
   3. Putting words together in a brief manner
   4. Determining the effectiveness of your plant
   5. Avoiding repetitive statements

9. Reports written by other operators are very helpful in preparing a report. These reports may be obtained:
   1. By asking another operator for a copy of one of his reports
   2. By buying one
   3. By asking your plant consulting engineer to help you find a report
   4. By requesting a representative from a regulatory agency to assist in finding a report
   5. From an effective writing textbook

10. Books on report writing may be:
    1. Obtained from a library
    2. Found in most treatment plants
    3. Obtained by writing the publisher
    4. Found in most homes
    5. Of no use to an operator

11. Well-kept records will make the task of writing reports much easier.
    1. True
    2. False

12. Entries on data sheets should be written in ink, because lead pencil entries may smudge and can be altered or erased.
    1. True
    2. False

ANSWERS

1. Unusual happenings should be recorded and described because they have an important influence on the interpretation of laboratory analyses describing the operation and efficiency of your plant and the condition of the receiving water. Also they could prove very helpful to the operator in case of an accident.
2. Records should frequently be evaluated to determine if your plant is operating properly and to identify any developing difficulties before they can become serious problems.
3. The purpose of monthly and annual reports is to provide a brief description of the operation of your plant for the benefit of management and regulatory agencies. See Section on Importance of Records.
4. Planning, organizing, directing, controlling
5. Planning - looking ahead, using factural information and experience to decide on a specific course of action to achieve a desired result.

True or False

1. False
2. False
3. False
4. False
5. False or True. Mainly fits in Organizing Function but cannot be seperated from Directing Function.
6. False
7. False (directing)
8. True
9. False (planning)
10. False
11. False
12. False

Fill-In

1. Records are important to:
    a. Document plant performance, efficiency, and problems
    b. Justify budget requests
    c. Provide design criteria for remodeling, expansion, and new processes
    d. Verify observations of plant operation
    e. Help if legal action is threatened
    f. Document quality of receiving waters
    g. Report preparation for supervisors and requlatory agencies
    h. Identify significant departures from normal values and take corrective action
    i. Show type and frequency of maintenance of operating units

Multiple Choice

1. 2. Communicate to management the accomplishemnts of you and your plant
   3. Can serve to justify a plant budget
   5. Explain to the public the operation and function of your plant

2. 1. Provide essential information when a plant is modified or expanded
   2. Show type and frequency of maintenance of operating units
   5. Provide data required by regulatory agencies

3. 1. Operation
   2. Inventory
   3. Complaints
   5. Maintenance

4. 2. Smith cleaned clarifier weirs today.
   3. Switched chlorine feed from No. 2 cylinder to No. 1.
   4. Heavy thunderstorm hit north end of town around 3 PM and lasted for approximately 15 minutes.
   5. Mayor Charles visited plant and discussed some recent odor complaints by plant neighbors.

5. 1. Evaluated
   4. Used as indicators of plant operation and maintenance

6. 1. Prevent the operator from getting a pay raise
   2. Indicate to management that the operator doesn't know what he is doing
   3. Indicate to the regulatory agency that the plant is not operating efficiently
   4. Convince the public that they shouldn't spend any more money on the plant
   5. Indicate that the operator doesn't care about his job

7. 2. Knowledge of the subject
   3. A good typewriter (ie. also important if report is typed.)
   4. Organizing the report to present ideas in a logical fashion
   5. Using facts and figures

8. 1. Use of correct grammar
   2. Elimination of needless words
   3. Putting words together in a brief manner
   5. Avoiding repetitive statements

9. 1. By asking another operator for a copy of one of his reports
   3. By asking your plant consulting engineer to help you find a report
   4. By requesting a representative from a regulatory agency to assist in finding a report

10. 1. Obtained from a library
    3. Obtained by writing the publisher

11. 1. True

12. 1. True